THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

WIN A MICROCHIP XLP 8-bit Development Board

USING A WIDEBAND O2 SENSOR IN YOUR CAR – PART 1

Accurate measurement of air/fuel ratios for engine tuning

DIGITAL CAPACITOR LEAKAGE METER

- Works with any type of capacitor
- Measure leakage currents down to 100nA
- Test voltages from 10V to 100V
- Very simple to operate

ONE-OF-NINE SWITCH INDICATOR

A track-in-use indicator for model railways

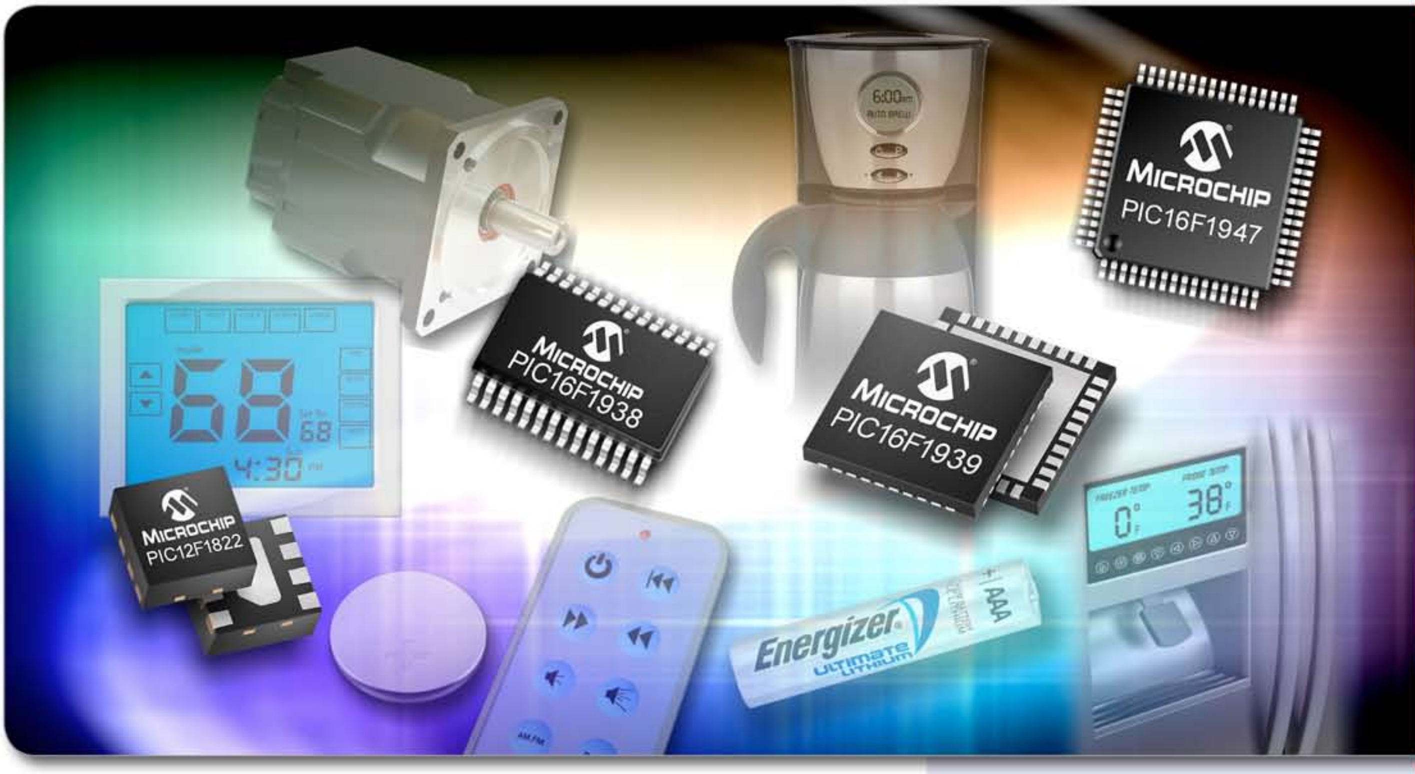
PLUS

PRACTICALLY SPEAKING, READOUT, NETWORK, CIRCUIT SURGERY, TECHNO TALK

$8.99US £4.25UK
NOV 2011 PRINTED IN THE UK
11
0 74470 07806 7

Low-Power Microcontrollers for Battery-Friendly Design

Microchip Offers Lowest Currents for Active and Sleep Modes



Extend the battery life in your application using PIC® microcontrollers with nanoWatt XLP Technology and get the industry's lowest currents for Active and Sleep modes.

Microchip's peripheral-rich PIC12F182X, PIC16F182X and PIC16F19XX families offer Active currents of less than 50 µA and Sleep currents down to 20 nA. These products enable you to create battery-friendly designs that also incorporate capacitive touch sensing, LCD, communications and other functions which help differentiate your products in the marketplace.

Microchip's Enhanced Mid-range 8-bit architecture provides up to 50% increased performance and 14 new instructions that result in up to 40% better code execution over previous-generation 8-bit PIC16 MCUs.

PIC12F182X and PIC16F182X families include:

- Packages ranging from 8 to 64 pins
- mTouch™ capacitive touch-sensing
- Multiple communications peripherals
- Dual I²C™/SPI interfaces
- PWM outputs with independent time bases
- Data signal modulator

PIC16F19XX family includes:

- mTouch capacitive touch-sensing
- LCD drive
- Multiple communications peripherals
- More PWM channels, with independent timers
- Up to 28 KB of Flash program memory
- Enhanced data EEPROM
- 32-level bandgap reference
- Three rail-to-rail input comparators

GET STARTED IN 3 EASY STEPS

1. View the Low Power Comparison videos
2. Download the Low Power Tips 'n Tricks
3. Order samples and development tools
   www.microchip.com/XLP

PIC16F193X 'F1' Evaluation Platform - DM164130-1

microchip DIRECT
www.microchipdirect.com

www.microchip.com/xlp

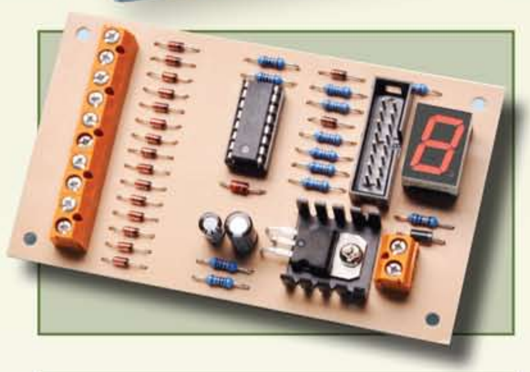
MICROCHIP

ISSN 0262 3617
• PROJECTS • THEORY •
• NEWS • COMMENT •
• POPULAR FEATURES •
VOL. 40. No 11 November 2011

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

www.epemag.com



Projects and Circuits

Series and Features

Regulars and Services

Our December 2011 issue will be published on Thursday 10 November 2011, see page 80 for details.

VOL. 40 No. 11 NOVEMBER 2011

EVERYDAY PRACTICAL ELECTRONICS

Progress, gimmicks and headaches

Anyone with their eyes open in the High street, and in particular readers of Barry Fox's excellent column, will know that one of the big technological pushes of recent times is 3D TV. This is the latest in a number of recent 'advances' designed to part us from our money and upgrade our ordinary TV. Everyone will have their own opinion on what they like, and, just as important, what they can afford, so what follows is purely a personal perspective.

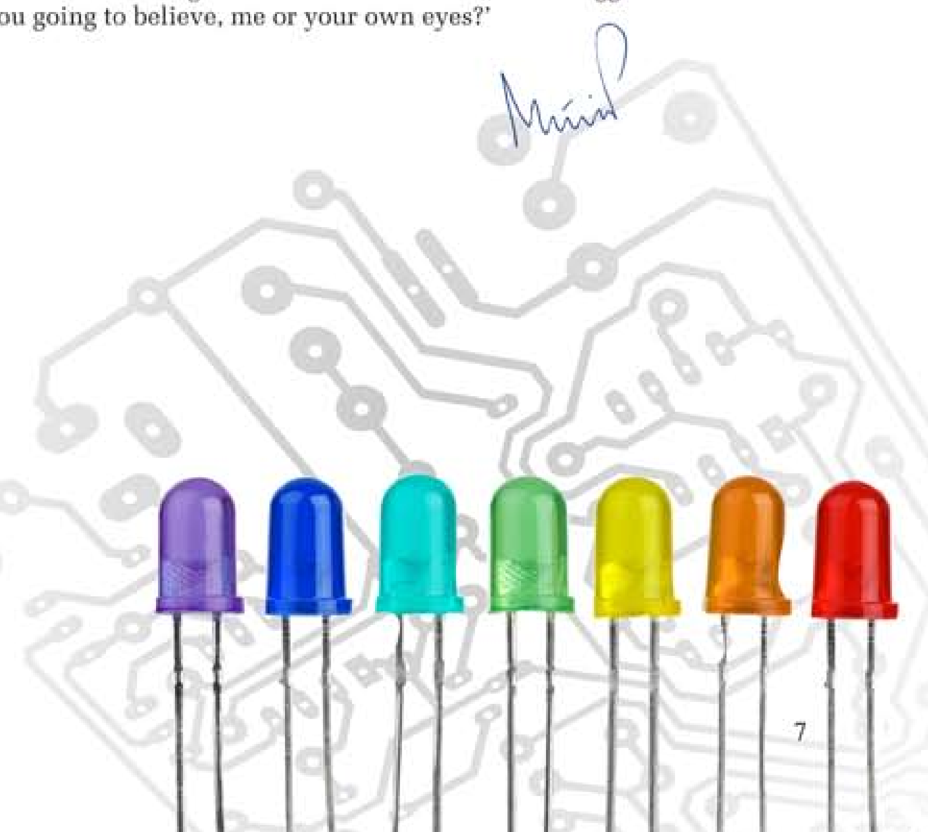
First, a confession; incredibly, I still use a 1987 Sony Trinitron CRT (cathode ray tube for our younger readers!) television, albeit fed with a cable signal via SCART. I realise that in many people's eyes this make me so far behind the curve of progress that I really have no right to pontificate on anything televisual, but bear with me for a few lines.

Photography is one of my hobbies, and there I am very much up to date with the latest technology, and go to great lengths and (excessive) expense to get the digital image I want. I know what looks good, natural, crisp, colour balanced and above all, pleasing to the eye – mine at least.

But, and it's a very big but, when I go into a television show room and look at some pretty high-end TVs, what I see is typically an array of gruesome, over-saturated, pixelated, low dynamic range horrors. Upping the pixel count and then extending the image into 3D does not make things any better. Quite the opposite, I get a headache after watching 3D, but that may be just me.

When I first bought my Sony TV it was considered quite large, now it is really rather average. For the first five minutes after switch on I can see raster scan lines and a rather nasty green tinge, but eventually it warms up and I get what I think is a nice picture. It is a little on the 'warm' side, not HD, but it is easy to watch and does not give me a headache. Like me, it is getting older and crankier, and I know that sooner rather than later I will need to buy a replacement, but I am in no hurry.

My views are definitely not a recommendation to follow a particular technological route, but when faced with a TV salesman I would caution you to remember the great Groucho Marx's line to the suggestible: 'Who are you going to believe, me or your own eyes?'



Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS
EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 880299. **Fax:** (01202) 843233.
Email: enquiries@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

READERS' TECHNICAL ENQUIRIES
Email: techdept@wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

NEWS

A roundup of the latest Everyday News from the world of electronics

Report from Berlin IFA by Barry Fox

The organisers of the September *IFA Electronics Show* in Berlin, and their rivals in the USA, who stage the January *Consumer Electronics Show* in Las Vegas, continue to compete with claims to be the world's major and largest event.

Both events are now so large, and bedevilled by bewildering floor plans that no visitor can hope to see everything. Also, both attract so many journalists (and freeloaders) that major press conferences are so overcrowded and oversubscribed that anyone wanting to be sure of getting into one conference must sacrifice the one before it.

Samsung's event at IFA, for instance, was once again held in a very small room, and thus was as hot as a sauna. There were more people outside unable to get in, or escaping for fresh air, than there were inside.

Berlin is promoted as a wired city, and IFA's theme was connectivity; however, the broadband connection in the press room slowed in use to dial-up speed. Also, although IFA is an IT showcase, the organisers had introduced a new online press registration system that even some of the organising team admitted they did not understand; for example, how to submit an application, and what electronic information to attach.

The net result was that journalists were walking round with a 'personal, non-transferable' user-printed badge that showed the same ID picture of the same unnamed lady. And because the badges had often been printed on home printers with less than perfect paper, the barcode readers at the show gates and booths had difficulty reading them.

Brainstorm

Last year at IFA, Sony launched a rival to iTunes with the name Qriocity, which few people could spell or pronounce. This year, Sony sidelined the name Qriocity and unveiled a 3D video headset that looks like a sci-fi brain machine.

The headset plugs into the mains and balances on the wearer's nose with a strap round the head to immerse the viewer in 3D sight and sound. 'Unrepentantly uncomfortable' was the instant verdict of one online review site.

This strange device clearly grew out of the lab prototype, which actor Tom Hanks mercilessly mocked when he was booked by Sony to read promotional praise at an electronics show in the USA in 2009. Hanks ignored Sony's script and adlibbed cruelly.

'Oh look, they're so cool and hip – you mean they are going to get even better than they are now?' Hanks sarcastically taunted Sony's boss Sir Howard Stringer when he tried on the headset; see: **www.youtube.com/watch?v=Ngf6hMWSmFA**

The good news is that image quality has greatly improved. Sony was also showing digital HD binoculars that record what they see. But, as a semi-serious birdwatcher, I have to wonder if anyone at Sony ever thought to ask a birder whether they would like to walk miles through marshy terrain with an electronic lump round their neck.

Suicidal fashion!

In its traditionally suicidal fashion, the electronics industry is now promoting the next big thing as no-glasses 'autostereoscopic' TV – while still trying to sell active and passive glasses 3DTVs. Toshiba promises a no-glasses set for 8000 euros this Christmas. Although this will be too costly for most people, first adopters will grab one, and the tabloid press will run gee-whiz, 'what's new' stories.

A model event

Toshiba's press conference and the technical briefing that followed were widely hailed as a model event. Hard facts, no time wasted on corporate puff and a frank and useful question and answer session. Several journalists publicly thanked Toshiba and wished that other Japanese and Korean companies – who stick to scripts, book celebrity presenters (like Tom Hanks!) and duck all questions – would follow suit.

Super high resolution TV

Sharp's booth was interesting for having only one 3D TV on show, and concentrating most interest on Super Hi Vision, the new super high quality 2D system developed by Japanese state broadcaster NHK. An 85' 8k/4k TV (with 7680 x 4320 resolution) was showing footage from Japanese state broadcaster NHK. The extreme natural clarity adds more depth than 3D.

Although Samsung was still promoting active shutter glasses 3D, recent patent searches show that the company is busy developing its own no-glasses solutions; and at IFA, Samsung was putting as much emphasis on smart connected TV as 3D.

Philips' Chinese tie up

Philips is hedging bets with a TV range that includes both active and passive glasses 3D sets, and at IFA was showing a very impressive no-glasses prototype. Philips has recently signed to merge its TV business with Chinese giant TPV, which makes one third of all the world's monitor screens.

With manufacturing power like that, Philips TPV really could make no-glasses 3D the next big thing.

New 8-bit PIC microcontrollers

Microchip's PIC10F(LF)32x and PIC1xF(LF)150x MCUs (available in 6- to 20-pin packages) feature new peripherals, including configurable logic cells (CLCs), complementary waveform generators (CWGs) and numerically controlled oscillators (NCOs), which introduce new functionality to low pin-count MCUs.

These general-purpose MCUs expand the reach of the PIC10F, PIC12F and PIC16F families, and support new applications for microcontrollers. They enable designers to enhance the functionality, reduce design size, and decrease the cost and power consumption for products such as small kitchen appliances; interior automotive lighting; consumer power tools; utility meters and other applications. For more details, see: **www.microchip.com/get/X792**

Microchip's new low pin-count MCUs come with a host of features

Intel computing runs fast and efficiently

Intel has been demonstrating its latest IC research achievements. Its new 'Near Threshold Voltage Processor' is a concept processor core that can tune power use so low that it can be powered off a small solar cell.

Most digital designs operate at nominal voltages of about 1V. NTV circuits operate around 400 to 500mV – very close to the 'threshold' voltage at which transistors turn on and begin to conduct current.

It is challenging to run electronics reliably at such reduced voltages. To put it simply, the difference between a '1' and a '0' in terms of electrical signal levels become very small, so a variety of noise sources can cause logic levels to be misread, leading to functional failures. The benefit, however, is that energy consumption reaches an absolute minimum in the NTV regime, with a sizeable 5 to 10 times improvement over conventional operation.

Several years of research went into realising the first NTV processor. Intel had to develop NTV-aware techniques to improve design robustness for reliable operation. The result is a 'heat-sink-free' processor core that can be placed in NTV mode at five-times better energy efficiency.

The processor also provides wide dynamic operational range and can run at higher frequencies (10x) when performance is needed. The new 'always-on' – yet 'ultra low power state' can keep applications running and is ideal whenever computing demands are modest.

This research could lead to the integration of NTV technology across a wide range of future products, taking 'always on' to a new level. For instance, this could be useful for smart phones, tablets and other devices, allowing 'one' design to efficiently scale for many products.

For the future, one goal of NTV research is to enable 'zero power' architectures, where power consumption is so low that entire digital devices could be powered off solar energy, or from the energy that surrounds us every day in the form of vibrations and ambient wireless signals. This would yield unfettered freedom, meaning users could just leave power cords and chargers at home or in the office.

The stacked plates in Intel's memory cube

Hybrid memory cube

Intel have also been showing off a potentially important new memory technology, claimed to be the 'fastest and most efficient' Dynamic Random Access Memory (DRAM) ever built.

Produced in collaboration with Micron Technology, the two companies worked together to jointly develop and specify a high-bandwidth memory architecture. This hybrid-stacked DRAM prototype, known as the Hybrid Memory Cube (HMC), is the world's highest bandwidth DRAM device, with sustained transfer rates of 1 terabit per second (trillion bits per second). On top of that, it is also the most energy efficient DRAM ever built when measured in number of bits transferred versus energy consumed.

This groundbreaking prototype has ten times the bandwidth and seven times the energy efficiency of even the most advanced DDR3 memory module available.

Intel hope these developments will have a fundamental impact on data centres and supercomputers that thirst for low-power high-bandwidth memory accesses.

Do it quicker with a stripper

Ideal's 'Lil' Ripper Stripper'

Ideal has launched the Lil' Ripper Stripper, a low-cost, handy multi-function wire stripper for flat cable. The tool incorporates three separate stainless steel blades, which can be used to rip, clip and strip flat cable in quick and clean motions. For further information, Tel: **+44 (0)1952 444446**, *or visit:* **www.idealindustries.co.uk**

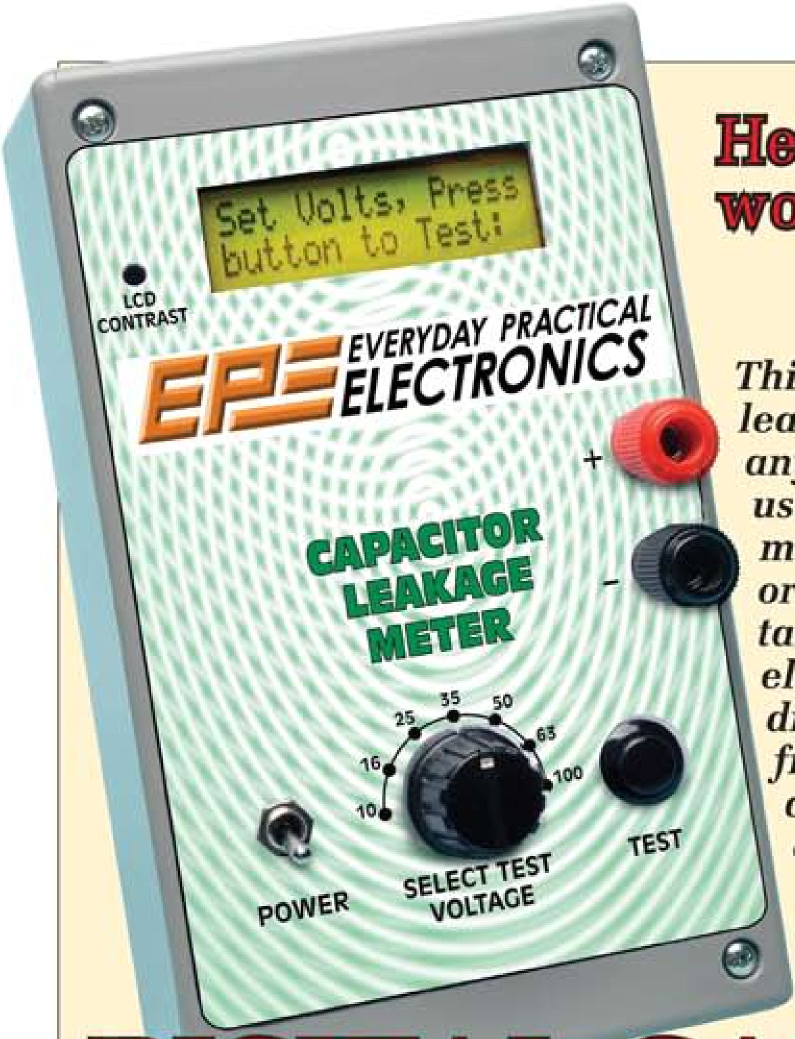
.scot proposal

The Internet Corporation for Assigned Names and Numbers (ICANN), the international regulatory body for domain space, proposes to expand the number of generic Top Level Domains (gTLDs) and will be inviting applications.

The Scottish Government has decided to back public 'Dot Scot' registry so that .scot TLD will be a community-based public resource rather than a private asset. The Scottish Government has established a Policy Advisory Board to represent its own interests and those of the wider community who support the concept of a .scot internet domain. Whether or not this will be followed by .wal, .nir and .eng remains to be seen!

Dead Sea scrolls brought alive

For those with an interest in religion or history, Google and the Israel Museum have put online some of the oldest biblical documents in existence – the Dead Sea Scrolls. *The project allows users to examine these most ancient manuscripts close up, see:* **http://dss.collections.imj.org.il**



Here's one for the workbench or toolbox!

This instrument can perform a leakage current test on almost any type of capacitor in current use, including ceramic, mica, monolithic, metallised polyester or paper, polystyrene, solid tantalum and aluminium electrolytics. There are seven different standard test voltages from 10V to 100V, so most capacitors can be checked at or close to their rated voltage. Leakage currents can also be measured, from almost 10mA down to less than 100nA.

DIGITAL CAPACITOR LEAKAGE METER

by JIM ROWE

IN THEORY, capacitors are not supposed to conduct direct current – apart from a small amount when a DC voltage is first applied to them and they need to 'charge up'.

And with most practical capacitors using materials like ceramic, polyester or polystyrene, or even waxed paper as their insulating dielectric, the only time they do conduct any DC is during charging.

That's assuming they haven't been damaged, either physically or electrically, or that their dielectric has not deteriorated with the passage of time. In that case, they may well have a significant DC 'leakage current' and need to be replaced.

Leakage matters

But as many readers will be aware, things are not this clear cut with electrolytic capacitors, whether they be aluminium or tantalum.

Even brand new electrolytic capacitors conduct a small, but measurable DC current, even after they have been connected to a DC source for sufficient time to allow their dielectric oxide layer to 'form'. In other words, all electrolytic capacitors have a significant leakage current, even when they are 'good'.

The range of acceptable leakage current tends to be proportional to both the capacitance and the capacitor's rated voltage. Have a look at the figures in the Capacitor Leakage Current Guide panel. The current levels listed there are the maximum allowable before the capacitor would be regarded as faulty.

Commercially available capacitor leakage current meters are expensive (hundreds of pounds), making this Capacitor Leakage Meter an attractive proposition, since it will cost a *great* deal less.

It's easy to build and provides seven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V and 100V, which will cover the majority of capacitors that most readers will be

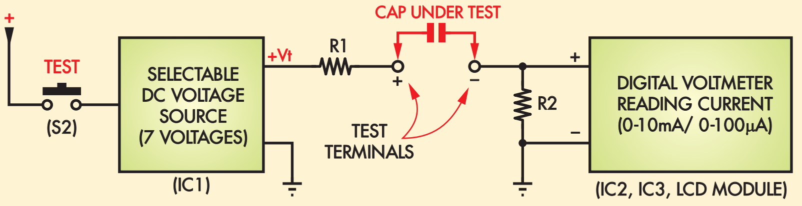


Fig.1: block diagram of the Digital Capacitor Leakage Meter. It consists of two sections, a selectable DC voltage source based on IC1 and a digital current meter (it's actually a voltmeter set up to read current), based on IC2, IC3 and the LCD module.

using. Built into a compact plastic box, it's battery powered (6 × 1.5V AA alkaline cells) and therefore fully portable. This makes it suitable not only for the workbench, but also for the service technician's toolbag.

The meter has a simple presentation in its plastic case. The lid carries the 2-line × 16-character backlit LCD module, as well as the test terminals, power and test switches, and also the 7-position rotary selector switch.

How it works

The Capacitor Leakage Meter's operation is quite straightforward, as you can see from the block diagram of Fig.1 above. There are two circuit sections, one is a selectable DC voltage source, which generates preset test voltages when the TEST button is pressed.

The other circuit section is a digital voltmeter, which is used to measure any direct current passed by the 'capacitor under test'. We use a voltmeter to make the measurement because any current passed by the capacitor flows via resistor R2. The voltmeter measures the voltage drop across R2 and is arranged to read directly in terms of current.

So that's the basic arrangement. The reason for resistor R1 being in series with the output from the test voltage source is to limit the maximum current that can be drawn, in any circumstances. This prevents damage to either the voltage source or the digital voltmeter sections in the event of the capacitor under test having an internal short circuit. It also protects R2 and the digital voltmeter section from overload when a capacitor (especially one of high value) is initially charging up to one of the higher test voltages.

Resistor R1 has a value of 10kΩ, which was chosen to limit the maximum charging and/or short circuit current to 9.9mA, even on the highest test voltage range (100V).

The digital voltmeter is configured as an auto-ranging current meter, with two current ranges selected by switching the value of shunt resistor R2. When TEST button S2 is first pressed, the voltmeter switches the value of R2 to 100Ω, to provide a 0 to 10mA range for the capacitor's charging phase. Only when (and if) the measured current level falls below 100μA does it switch the value of R2 to 10kΩ, to provide a 0 to 100μA range for more accurate measurement of leakage current.

Circuit description

Now have a look at Fig.2, the full circuit diagram of the Digital Capacitor Leakage Meter.

The selectable DC voltage source is based around IC1, an MC34063 DC/DC controller IC. It is used in a step-up or 'boost' configuration in conjunction with autotransformer T1 and fast switching diode D3. Transformer T1 is based on a ferrite pot core and has 15 turns on its primary and 45 turns on its secondary, effectively giving a three-times boost to the input voltage.

However, we set the circuit's actual DC output voltage by varying the ratio of the voltage divider in the converter's feedback loop, connecting from the cathode (K) of D3 back to IC1's pin 5. Here the feedback voltage is compared with an internal 1.25V reference.

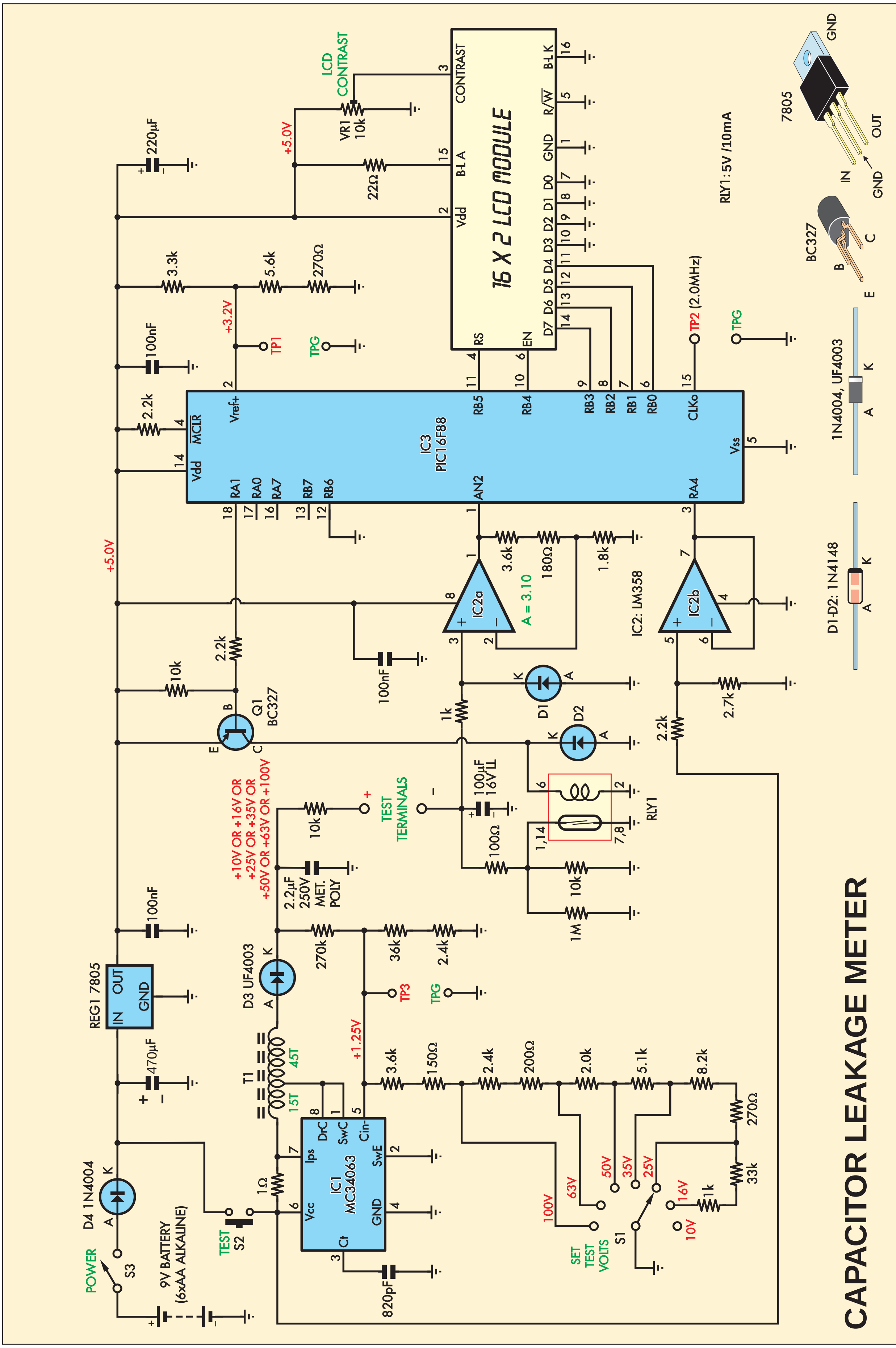
A 270kΩ resistor forms the top arm of the feedback divider, while the 36kΩ and 2.4kΩ resistors from IC1 pin 5 to ground form the fixed component of the lower arm. These give an initial division ratio of 308.4kΩ/38.4kΩ or 8.031:1, to produce a regulated output voltage of 10.04V.

This is the converter's output voltage when switch S1 is in the 10V position.

CAPACITOR LEAKAGE CURRENT GUIDE

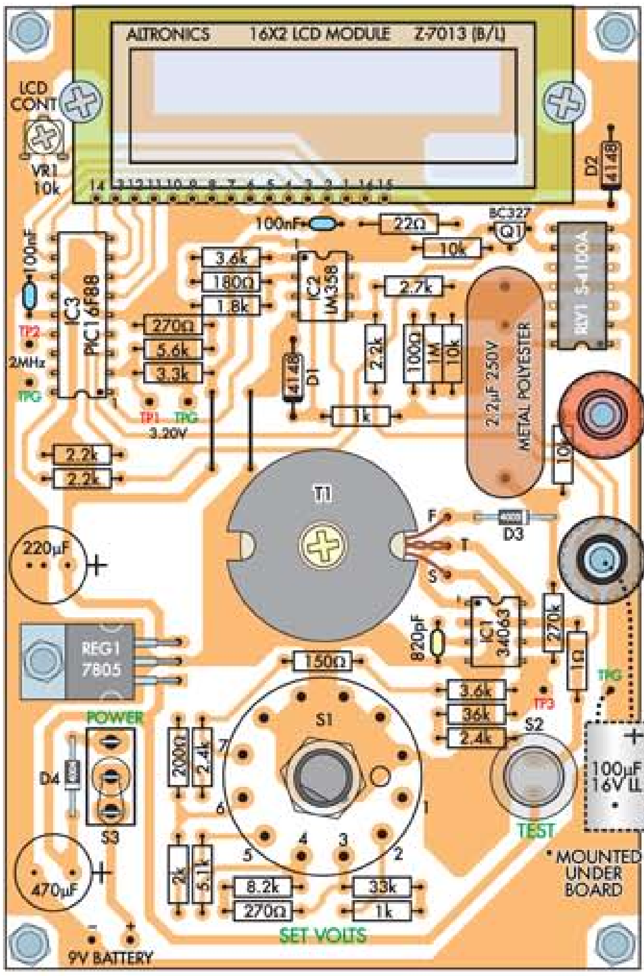
TYPE OF CAPACITOR	Maximum leakage current in microamps (µA) at rated working voltage						
	10V	16V	25V	35V	50V	63V	100V
Ceramic, Polystyrene, Metallised Film (MKT, Greencap etc.), Paper, Mica	LEAKAGE SHOULD BE ZERO FOR ALL OF THESE TYPES						
Solid Tantalum* < 4.7µF	1.0	1.5	2.5	3.0	3.5	5.0	7.5
6.8µF ⋮ 47µF	1.5 ⋮ 10	2.0 ⋮ 10	3.0 ⋮ 15	4.0 ⋮ 16	6.5 ⋮ 17	7.0 ⋮ 19	9.0 ⋮ 24
Standard Aluminium Electrolytic# <3.3µF	5.0	5.0	5.0	6.0	8.0	10	17
4.7µF ⋮ 10µF	5.0	5.0 ⋮ 8.0	6.0 ⋮ 13	8.0 ⋮ 18	12 ⋮ 25	15 ⋮ 35	23 ⋮ 50
15µF ⋮ 100µF	8.0 ⋮ 50	11 ⋮ 230	19 ⋮ 300	25 ⋮ 330	38 ⋮ 420	100 ⋮ 500	230 ⋮ 600
150µF ⋮ 680µF	230 ⋮ 500	280 ⋮ 600	370 ⋮ 780	430 ⋮ 950	520 ⋮ 1100	600 ⋮ 1300	730 ⋮ 1560
1000µF ⋮ 4700µF	600 ⋮ 1300	730 ⋮ 1590	950 ⋮ 2060	1130 ⋮ 2450	1340 ⋮ 2900	1500 ⋮ 3300	1900 ⋮ 4110

* Figures for Solid Tantalum capacitors are after a charging period of one minute.
# Figures for Aluminium Electrolytics are after a charging/reforming period of three minutes.



CAPACITOR LEAKAGE METER

Fig.2: the circuit diagram of the capacitor leakage meter. Some of the resistors, especially in the string attached to S1, are not values you see every day – but it's important that the correct resistors are used to achieve the correct voltage steps.



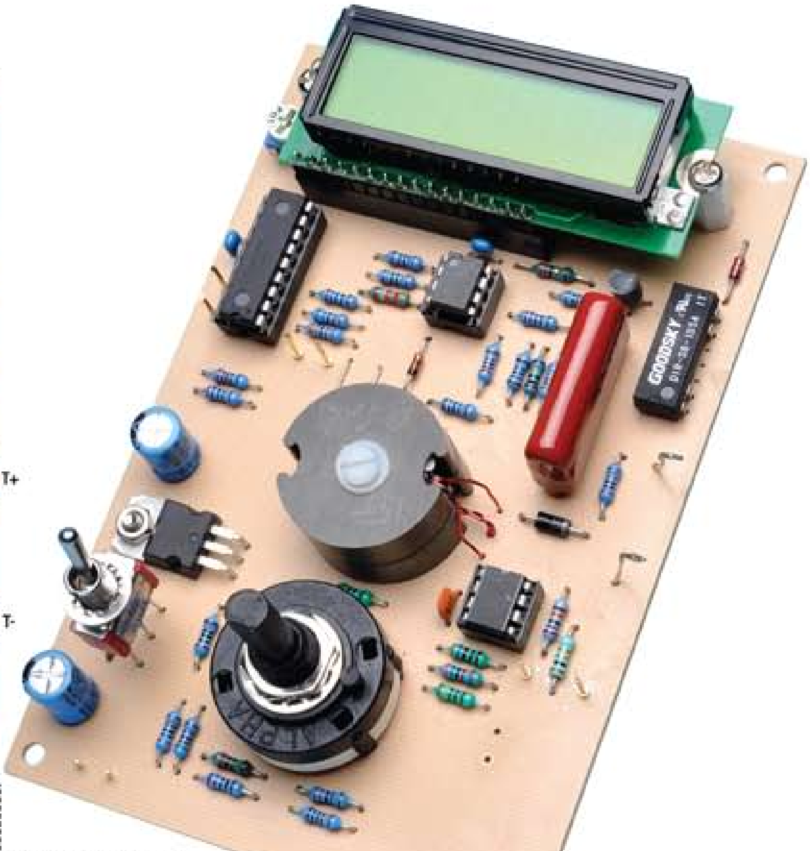


Fig.3 (left): the PC board component overlay, along with a slightly reduced photo at right. The two vacant holes (lower right of pic) are for the 'Test' button, S2; while the bare leads at the right edge onnect to the two terminals (T+ and T–).

When S1 is switched to any of the other positions, additional resistors are connected in parallel with the lower arm of the feedback divider, to increase its division ratio and hence increase the converter's output voltage.

For example, when S1 is in the 25V position, it connects the 270Ω, 8.2kΩ, 5.1kΩ, 2.0kΩ, 200Ω, 2.4kΩ, 150Ω and 3.6kΩ resistors (all in series) in parallel with the divider's lower arm, changing the division ratio to 283.954kΩ/13.954kΩ or 20.35:1. This produces a regulated output voltage of 25.44V. The same kind of change occurs in the other positions of S1, producing the various preset output voltages shown.

Although the test voltages shown are nominal, if you use the specified 1% tolerance resistors for all of the divider resistors they should all be within ±4% of the nominal values because the 1.25V reference inside the MC34063 is accurate to within 2%.

IC1 doesn't generate the desired test voltage all the time – only when test pushbutton S2 is pressed and held down. This is because IC1 only receives power from the battery when S2 is closed.

When the converter circuit operates, it generates the desired test voltage across the 2.2µF/250V metallised polyester reservoir capacitor. It is connected to the *positive* test terminal via the 10kΩ current-limiting resistor (R1 in Fig.1).

Digital voltmeter

The digital voltmeter is based on an LM358 dual op amp (IC2) and a PIC16F88 microcontroller (IC3). The micro provides the 'smarts' to calculate the leakage current and display the value on the LCD module.

The 100Ω, 1MΩ and 10kΩ resistors connected between the *negative* test terminal and ground correspond to the current shunt labelled R2 in Fig.1, with the contacts of reed relay RLY1 used to change the effective shunt resistance for the meter's two ranges.

For the 10mA 'charging phase' range, the reed relay connects a 'short circuit' across the parallel 1MΩ/10kΩ combination, making the effective shunt resistance 100Ω. For the more sensitive 100µA range, RLY1 is turned off, connecting the parallel 1MΩ/10kΩ resistors in series with the 100Ω resistor to produce an effective shunt resistance of 10kΩ.

The voltage drop developed across the shunt resistance (as a result of any current passed by the capacitor under test) is passed to the non-inverting input of op amp IC2a, half of the LM358. IC2a is configured as a DC amplifier with a voltage gain of 3.10, feeding the AN2 analogue input of IC3, the PIC16F88 micro.

Microcontroller IC3 compares the voltage from IC2a with a reference voltage of 3.2V fed into its pin 2 (Vref+). This reference is derived from the regulated +5V supply line via the voltage divider formed by the 3.3kΩ, 5.6kΩ and 270Ω resistors. After mathematical scaling inside IC3, the readings are then displayed on the 16×2 LCD module.

Parts List – Digital Capacitor Leakage Meter

1 PC board, code 826, available from the *EPE PCB* Service, size 127mm × 84mm
1 Plastic box, 157mm × 95mm × 53mm (UB1 size)
2 Binding post/banana jacks (1 red, 1 black)
1 16×2 LCD module, compact with LED backlighting
1 Mini DIL reed relay, SPST with 5V coil
1 Single-pole rotary switch, PC board mounting (S1)
1 Instrument knob, 16mm diameter with grub screw fixing
1 SPST pushbutton switch, push-to-make (S2)
1 SPDT mini toggle switch (S3)
1 Ferrite pot core pair, 26mm OD (T1)
1 Bobbin to suit pot core
1 10× AA battery holder (flat) or
1 4 × AA battery holder, flat **and**
1 2 × AA battery holder, side-by-side (see text)
1 3m length of 0.5mm diameter enamelled copper wire
2 12mm-long M3 tapped nylon spacers
4 25mm-long M3 tapped spacers
1 25mm-long M3 nylon screw with nut and flat washer
9 6mm-long M3 machine screws, pan head
4 6mm-long M3 machine screws, csk head
1 M3 nut
1 16-pin length of SIL socket strip
1 16-pin length of SIL pin strip
1 18-pin IC socket
2 8-pin IC sockets
8 1mm-diameter PC board terminal pins
1 0.5m length 0.7mm tinned copper wire (for mounting switches etc)

Semiconductors
1 MC34063 DC/DC converter controller (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 programmed microcontroller (IC3)
1 7805 +5V regulator (REG1)
1 BC327 *PNP* transistor (Q1)
2 1N4148 100mA signal diodes (D1,D2)
1 UF4003 ultrafast 200V/1A diode (D3)
1 1N4004 400V/1A diode (D4)

Capacitors
1 470µF 16V radial electrolytic
1 220µF 10V radial electrolytic
1 100uF 16V LL (low leakage) electrolytic
1 2.2µF 250V metallised polyester
2 100nF multilayer monolithic ceramic
1 820pF disc ceramic

Resistors (0.25W 1% metal film unless specified)

1 1MΩ	1 270kΩ	1 36kΩ	1 33kΩ	3 10kΩ	1 8.2kΩ	1 5.6kΩ
1 5.1kΩ	2 3.6kΩ	1 3.3kΩ	1 2.7kΩ	2 2.4kΩ	3 2.2kΩ	1 2.0kΩ
1 1.8kΩ	2 1kΩ	2 270Ω	1 200Ω	1 180Ω	1 150Ω	1 100Ω

1 22Ω 0.5W carbon
1 1.0Ω 0.5W carbon
1 10kΩ mini horizontal trimpot (VR1)

IC3 can sense when the testing of a capacitor begins because it monitors the supply voltage fed to IC1, when test switch S2 is pressed. This is because the supply voltage (about 8.4V) fed to pin 6 of IC1 is also fed to the non-inverting input (pin 5) of op amp IC2b, via a resistive divider formed by the 2.2kΩ and 2.7kΩ resistors. Since IC2b is connected as a unity-gain voltage follower, a logic 'high' is fed to pin 3 of IC3 (the RA4 input) as soon as switch S2 is pressed, and remains there as long as it is held down.

When S2 is released, the 2.7kΩ resistor pulls the voltage at pin 5 of IC2b down to 0V, causing the voltage at pin 3 of IC3 to fall to the same level. So IC3 can sense when a test begins and also when it ends, because of the logic level at its RA4 input.

As part of its internal firmware program, IC3 ensures that relay RLY1 is always energised to short out the 1MΩ and 10kΩ current-sensing resistors at the start of a new test, to allow for the capacitor's charging current. It does this by pulling its output pin 18 (RA1) down to the logic low level (0V), which turns on transistor Q1 and supplies current to the coil of RLY1.

Once the capacitor's current falls below 100µA, IC3 pulls its pin 18 high, turning off Q1 and the reed relay. This removes the short circuit across the 1MΩ and 10kΩ resistors, changing the effective current shunt resistance to 10kΩ, and hence switching the meter down to its more sensitive range.

Protection diodes

Diode D1 is included in the metering circuit to protect pin 3 of IC2a from damage due to accidental application of a negative voltage to the negative test terminal (from a previously charged capacitor, for example).

Diode D2 is there to protect transistor Q1 from damage due to any back EMF 'spike' from the coil of RLY1 when it is de-energised.

Trimpot VR1 adjusts the contrast of the LCD module for optimum visibility. The 22Ω resistor connected from the +5V supply rail to pin 15 of the LCD module provides the module's LED backlighting current. The resistor's value of 22Ω is a compromise between maximising display brightness and keeping battery drain to no higher than is necessary, to promote battery life.

As you can see, although the voltage source section of the circuit operates directly from the 9V battery (via polarity protection diode D4 and switch S2), the rest of the circuit operates from a regulated 5V rail, which is derived from the battery via REG1, a 7805 3-terminal regulator.

Winding the transformer

The step-up autotransformer (T1) has 60 turns of wire in all, wound in four 15-turn layers. As shown in the coil assembly diagram (Fig.4, right), all four layers are wound on a small nylon bobbin using 0.5mm-diameter enamelled copper wire. Use this diagram to help you wind the transformer correctly.

Here's the procedure: first you wind on 15 turns, which will neatly take up the width of the bobbin providing you wind them closely and evenly. Then to hold it down, cover this first layer with a 9mm-wide strip of plastic insulating tape or 'gaffer' tape.

Next take the wire at the end of this first layer outside of the bobbin (via one of the 'slots'), and bend it around by 180° at a point about 50mm from the end of the last turn. This doubled-up lead will be the transformer's 'tap' connection.

The remaining wire can then be used to wind the three further 15-turn layers, making sure that you wind them in the *same* direction as you wound the first layer. Each of these three further layers should be covered with another 9mm-wide strip of plastic insulating tape just as you did with the first layer, so that when all four layers have been wound and covered everything will be nicely held in place.

The 'finish' end of the wire can then be brought out of the bobbin via one of the slots (on the same side as the start and tap leads). Your wound transformer bobbin should fit inside the two halves of the ferrite pot core.

Just before you fit the bobbin inside the bottom half of the pot core, you need to prepare a small plastic washer. This washer provides a thin magnetic 'gap' in the pot core when it's assembled, to prevent the pot core from saturating when it's operating.

The washer is very easy to cut from a piece of the thin clear plastic that's used for packaging electronic components, like resistors and capacitors. This plastic is very close to 0.06mm thick, which is just what we need here. So the idea is to punch a 3 to 4mm diameter hole in a piece of this plastic using a leather punch or similar, and then use a small pair of scissors to cut around the hole in a circle, with a diameter of 10mm. Your 'gap' washer will then be ready to place inside the lower half of the pot core, over the centre hole.

Once the gap washer is in position, lower the wound bobbin into the pot core, and then fit the top half of the pot core. The transformer is now ready for mounting on the main PC board. To begin this step, place a nylon flat washer on the 25mm-long M3 nylon screw that will be used to hold it down on the board. Then pass the screw down through the centre hole in the pot core halves, holding them (and the bobbin and gap washer inside) together with your fingers. Then lower the complete assembly down in the centre of the board with the 'leads' towards the right, using the bottom end of the centre nylon screw to locate it in the correct position.

When you are aware that the end of the screw has passed through the hole in the PC board, keep holding it all together but up-end everything so you can apply the second M3 nylon flat washer and M3 nut to the end of the screw, tightening the nut so that the pot core is not only held together but also secured to the top of the PC board.

Once this has been done, all that remains as far as the transformer is concerned is to cut the start, tap and finish leads to a suitable length, scrape the enamel off their ends so they can be tinned, and then pass the ends down through their matching holes in the board so they can be soldered to the appropriate pads.

Don't forget to scrape, tin and solder both wires which form the 'tap' lead – if this isn't done, the transformer won't produce any output.

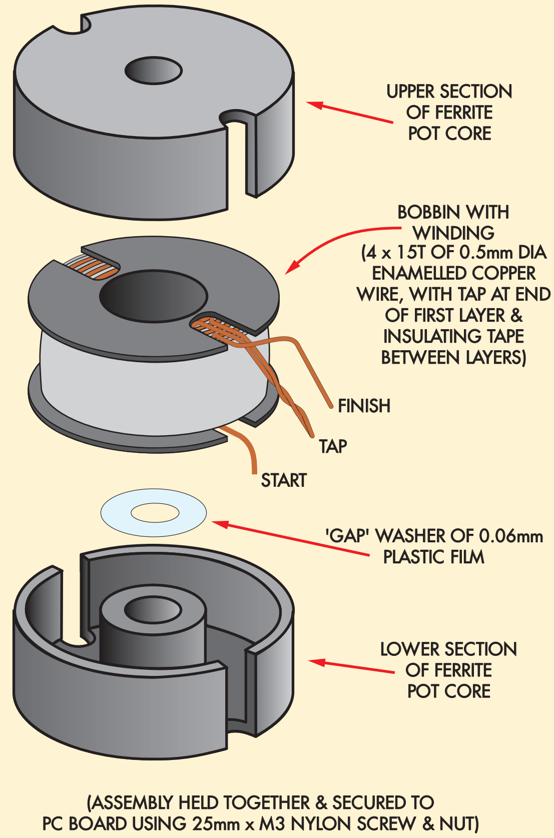


Fig.4. Ferrite pot core assembly details

The only other point which should be mentioned is that the PIC16F88 micro (IC3) operates from its internal RC clock, at close to 8MHz. A clock signal of one quarter this frequency (2MHz) is made available at pin 15 of IC3 and then at test point TP2, to allow you to check that IC3 is operating correctly.

Software

The software program files for the *Digital Capacitor Leakage Meter* will be available from the *EPE* website at: **www.epemag.com**.

Construction

Virtually all of the circuitry and components used in the Capacitor Leakage Meter are mounted on a single PC board measuring 127mm × 84mm. This board is available from the *EPE PCB Service*, code 826.

The board is supported behind the lid of the plastic box (size UB1: 157mm × 95mm × 53mm) which houses the meter. The six 1.5V AA alkaline cells used to provide power are mounted in one or two battery holders inside the main part of the box.

The main board is suspended from the lid of the box (which becomes the instrument's front panel) via four 25mm-long M3 tapped spacers. The LCD module mounts at the top end of the main board on two 12mm long M3 tapped nylon spacers. The DC/DC converter's pot core transformer (T1) mounts on the main board near the centre, using a 25mm-long M3 nylon screw and nut. Voltage selector switch S1 also mounts directly on the board, just below T1.

The only components not mounted directly on the main board are power

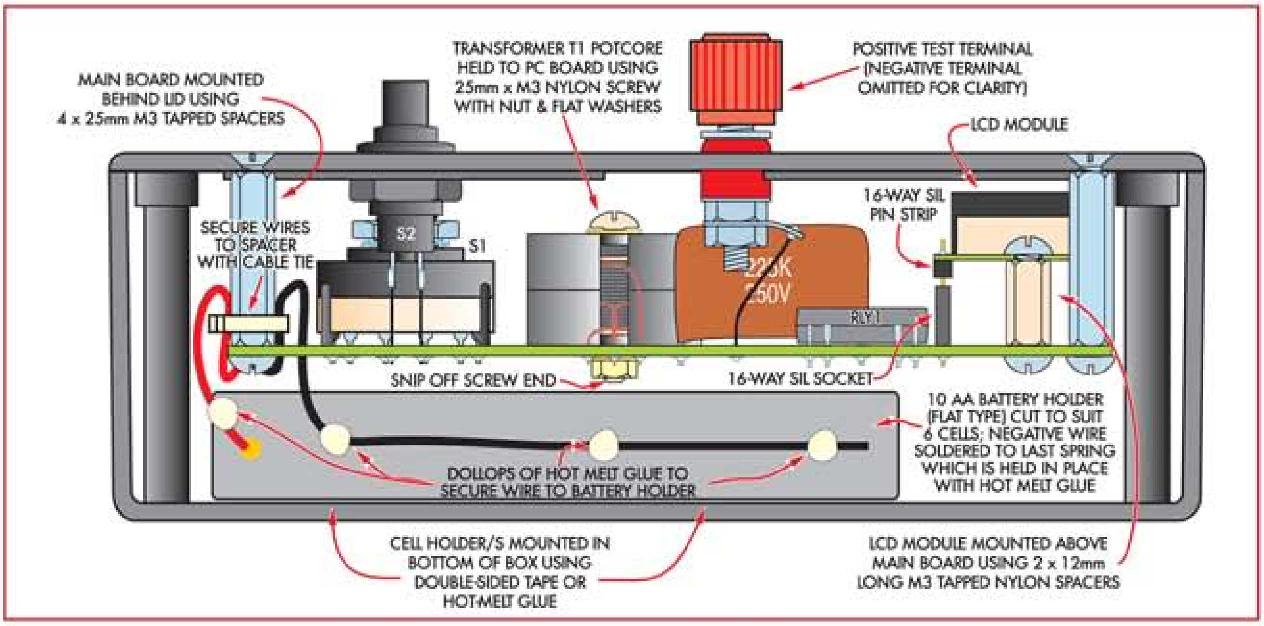


Fig.5. detailed assembly diagram of the completed project

switch S3, test switch pushbutton S2 and the two test terminals. These are all mounted on the box front panel, with their rear connection lugs extended down via short lengths of tinned copper wire to make their connections to the board.

All of these assembly details are shown in the diagrams and photos. The component overlay diagram for the PC board is shown in Fig.3, while the cross-sectional diagram, showing the PC board and batteries mounted inside the plastic case, is depicted in Fig.5.

Board assembly

To begin assembly of the PC main board, fit the two wire links, both located just to the upper left of the position for transformer T1. They are both short and above the board, so they're easily fashioned from resistor lead offcuts or tinned copper wire.

Next, fit the eight 1mm PC pins to the board – two for each of the three test point locations, and the final pair at lower left for the battery clip lead connections. Follow these with the sockets for IC1 and IC2 (both 8-pin sockets) and IC3 (an 18-pin socket).

Now you can fit all of the fixed resistors. These are all 1% tolerance metal film components, apart from the 1Ω resistor just to the right of IC1 and the 22Ω resistor at the top, just below the LCD module position. These latter components should be of the 0.5W carbon composition type.

When you are fitting all of the resistors, make sure you place each value in its correct position, as any mixups may have a serious effect on the meter's accuracy. Check each resistor's value with a DMM before soldering it into place.

With the fixed resistors in place, you can fit trimpot VR1, which goes up near the top left-hand corner of the board. Next, fit the small low-value capacitors, followed by the large 2.2µF metallised polyester unit, and finally, the three (polarised) electrolytics.

One of these, the 100µF low leakage electrolytic, solders under the PC board between the negative test terminal pad and the TPG pad. The positive capacitor lead connects to the negative test terminal pad, the negative lead goes to earth (see – Fig.3).

When fitting the mini DIL relay, make sure its locating spigot is at the bottom end.

These two photos of the assembled Capacitor Leakage Meter (one from each side) show the construction detail mirrored in the diagram above. It wouldn't hurt to secure the thin battery wires (red and black) to the nearby mounting pillar with a cable tie to prevent flexing/breaking the solder join at the PC stakes. We've shown this in the diagram above, but not in the prototype photos. Also, the 100µF capacitor soldered under the board (from – terminal to earth) is not shown in these photos.

Voltage range switch

You can now fit voltage selector switch S1, which has its indexing spigot at 3 o'clock. Just before you fit it, you should cut its spindle to a length of about 12mm and file off any burrs, so it is ready to accept the knob later on.

After S1 has been fitted to the board, remove its nut/lockwasher/position stopwasher combination, and turn the spindle by hand to make sure its at the fully anticlockwise limit. Then refit the position stopwasher, making sure that its stop pin goes down into the hole between the moulded '7' and '8' digits.

After this, refit the lockwasher and nut to hold it down securely, allowing you to check that the switch is now 'programmed' for the correct seven positions –- simply by clicking it through them by hand.

Final components

When the transformer has been wound and fitted to the board, you'll be ready to fit diodes D1 to D4. These are all polarised, so make sure you orientate each one correctly, as shown in Fig.3. Also ensure that the UF4003 diode is used for D3, the 1N4004 diode for D4 and the two 1N4148 signal diodes for D1 and D2.

After the diodes, fit transistor Q1, a BC327 *PNP* device. Then fit REG1, which is in a TO-220 package and lies flat on the top of the board with its lead bent down by 90° at a point about 6mm away from the body. The device is held in position on the board using a 6mm-long M3 machine screw and nut, which must be tightened *before* the leads are soldered to the pads underneath.

The final component to be mounted directly on the board is the 16-way length of SIL (single in-line) socket strip used for the 'socket' for the LCD module connections. Once this has been fitted and its pins soldered to the pads underneath, you'll be almost ready to mount the LCD module itself.

All that will remain before this can be done is to fasten two 12mm long M3 tapped nylon spacers to the board in the module mounting positions (one at each end) using a 6mm M3 screw passing up through the board from underneath, and then 'plugging' a 16-way length of SIL pin strip into the socket strip you have just fitted to the board. Make sure the longer ends of the pin strip pins are mating with the socket, leaving the shorter ends uppermost to mate with the holes in the module.

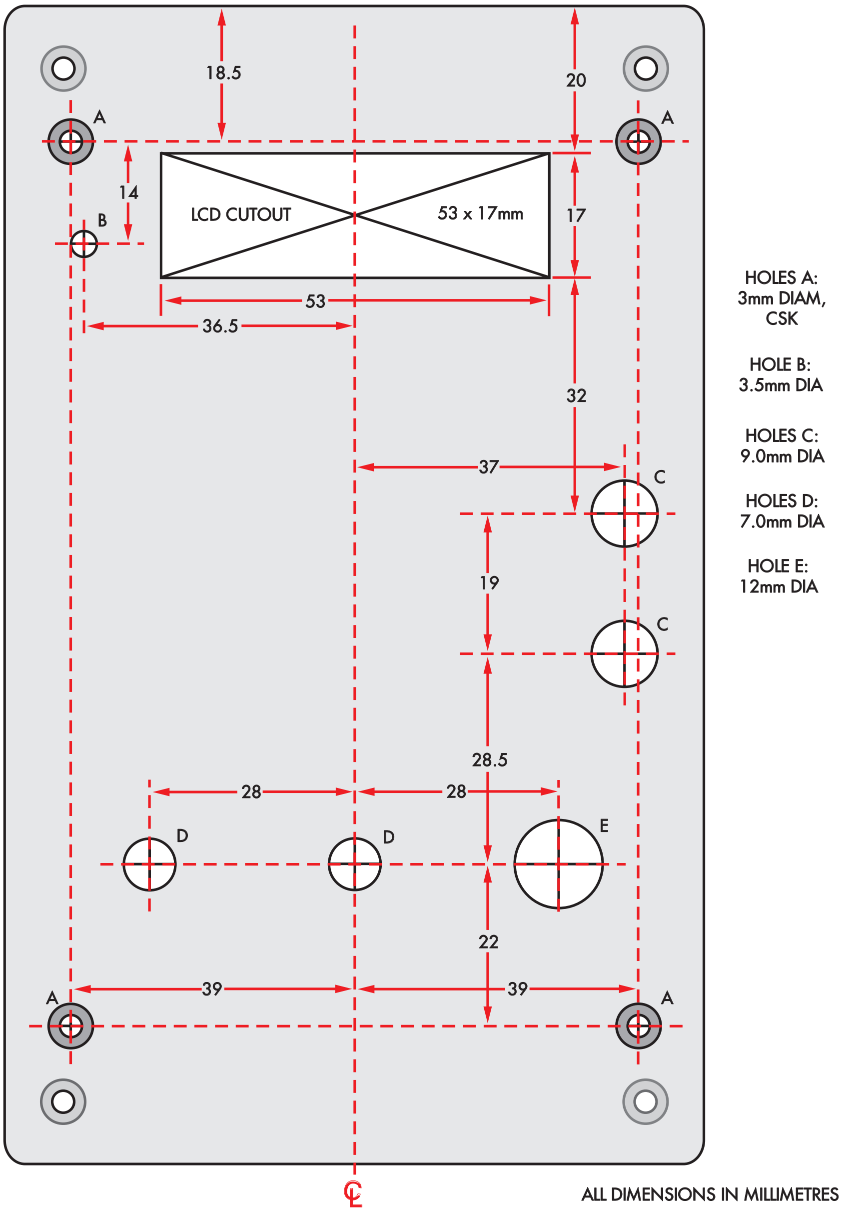


Fig.6: drilling and cutout detail for the lid of the UB1-size plastic box, from which hangs the PC board containing everything but the battery holder.

LCD module mounting

Now remove the LCD module from its protective bag, taking care to hold it between the two ends so you don't touch the board copper. Then lower it carefully onto the main board so that the holes along its lower front edge mate with the pins of the pin strip, allowing the module to rest on the tops of the two 12mm-long nylon spacers.

Now fit another 6mm M3 screw to each end of the module, passing down through the slots in the module and mating with the spacers. When the screws are tightened (but not *over* tightened) the module should be securely mounted in position.

The final step is to use a fine-tipped soldering iron to carefully solder each of the 16 pins of the pin strip to the pads on the module, to complete its interconnections.

After this is done, you can plug the three ICs into their respective sockets, making sure to orient them all as shown in Fig.3.

At this stage, your PC board assembly should be nearly complete. All that remains is to attach one of the 25mm-long mounting spacers to the top of the board in each corner, using

6mm-long M3 screws. Then the board assembly can be placed aside while you prepare the case and its lid.

Preparing the case

As the circuit requires 9V DC (and because a 9V DC battery won't last very long) we require six AA cells. Unfortunately, we couldn't find any 6xAA flat battery holders – they're only available in 1, 2, 4 and 10 cells.

You have a choice here – fit a 4-cell and a 2-cell holder and connect them in series, or cut down a 10-cell to accommodate six cells. We tried both, but chose the latter because arguably it looks neater.

If you cut down a 10-cell holder, you'll need to solder the negative wire to the spring connecting the last cell and almost certainly, glue the spring in place. We used hot-melt glue for this – just make sure you don't get any glue on the end of the spring itself and inadvertently insulate it! Hot-melt glue can also be used to secure the wires to the edge of the battery case.

There are no holes to be drilled in the lower part of the case, because the battery holder(s) can be held securely in place using strips of double-sided adhesive foam tape or hot-melt glue. But the lid does need to have some holes drilled, plus a rectangular cutout near the upper end for viewing the LCD.

The location and dimensions of all these holes are shown in Fig.6, which can also be used (or a photocopy of it) as a drilling template. The 12mm hole (E) for S2 and the 9mm holes (C) for the test terminals are easily made by drilling them first with a 7mm twist drill, and then enlarging them to size carefully using a tapered reamer.

The easiest way to make the rectangular LCD viewing window is to drill a series of closely-spaced 3mm holes just inside the hole outline, and then cut between the holes using a sharp chisel or hobby knife. Then the sides of the hole can be smoothed using small needle files.

We have prepared artwork for the front panel if you would like to make it look neat and professional. This can be photocopied from the magazine (Fig.7). The resulting copy can be attached to the front of the lid and then covered with self-adhesive clear film for protection. An alternative is to laminate the label using a heat laminator.

You might also like to attach a 60mm × 30mm rectangle of 1 to 2mm-thick clear plastic behind the LCD viewing window, to protect the LCD from dirt and physical damage. The 'window pane' can be attached to the rear of the lid using either adhesive tape or epoxy cement.

Once your lid/front panel is finished, you can mount switches S2 and S3 on it using the nuts and washers supplied with them. These can be followed by the binding posts used as the meter's test terminals. Tighten the binding post mounting nuts quite firmly, to make sure that they won't work loose with use. Then use each post's second nut to attach a 4mm solder lug to each, together with a 4mm lockwasher to make sure they don't work loose either.

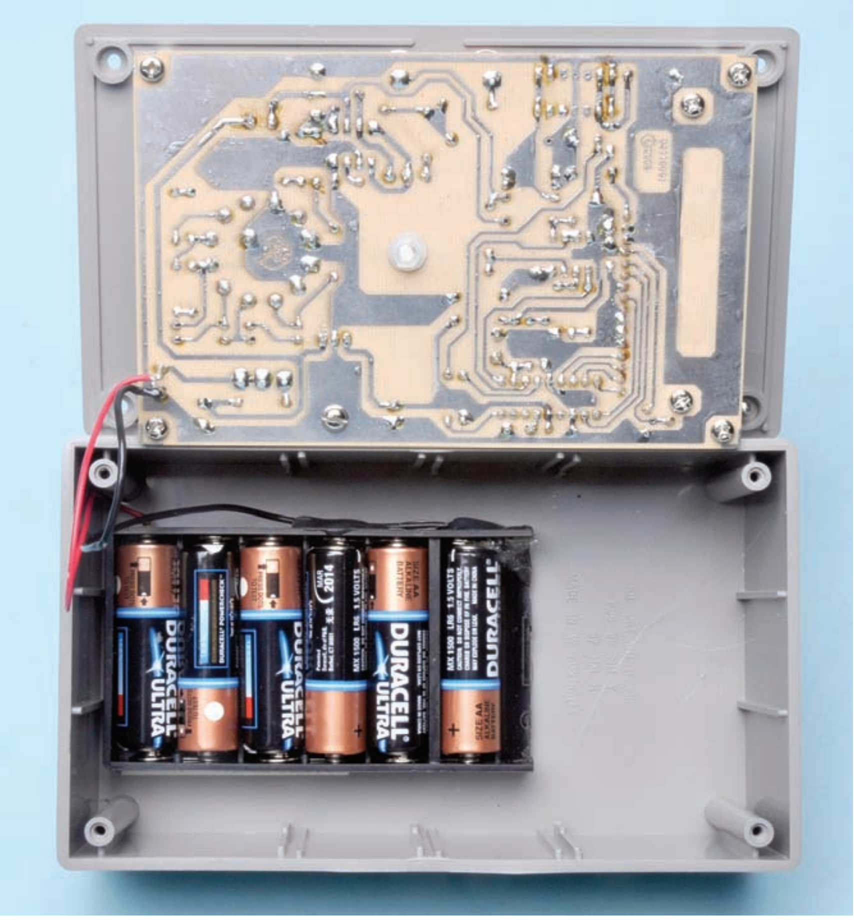
Now you can turn the lid assembly over, and solder 'extension wires' to the connection lugs of the two switches, and also the solder lugs fitted to the rear of the binding posts. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter).

Battery holder(s)

The next step is to mount the battery holder(s) in the main part of the case, preferably using double-sided adhesive foam or hot-melt glue, as mentioned earlier. At a pinch, you could even hold them in place with a strip of 'gaffer' tape.

If you opt for two battery holders, solder the bared end of the red wire from one battery clip lead to the black wire from the other clip lead, and carefully wrap this joint with insulating tape (or heatshrink sleeving) so that it can't accidentally come into contact with anything.

Then solder the remaining wire of each clip lead to its appropriate



Inside the box, just before the lid is screwed on. We elected to use a 'cut down' 10×AA battery holder to make a six-cell holder. Ideally, it should be cut slightly longer so that the last spring is still held in position. We used hot-melt glue to hold this spring in place and secure the wires to the battery case. The 100μF capacitor from the negative terminal to earth on the underside of the PCB (a late addition to ensure accuracy) is not shown in this photo.

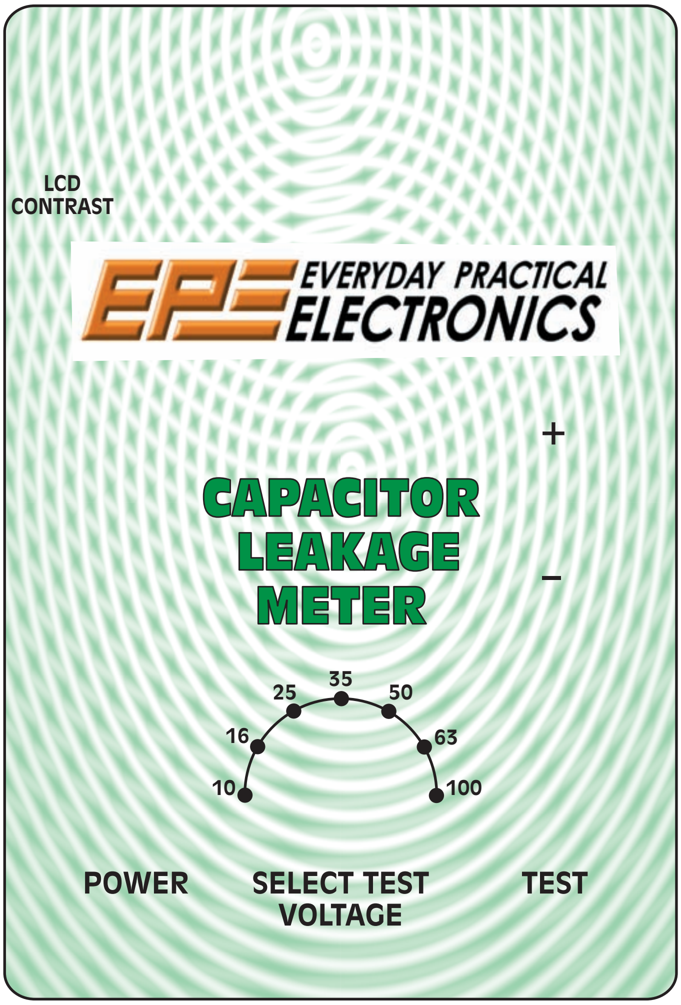


Fig.7: this front panel artwork is full size, so it can be photocopied (you won't be breaching copyright!) and printed out in glorious living colour. We'd cover it to protect the surface, either with self-adhesive clear film or with a heatset laminator (the latter is tougher). If you choose lamination, you should consider removing the LCD cutout first, thus providing a clear 'window' protecting the LCD.

terminal pin at bottom left of the PC board, directly below the position for power switch S3. The red wire should go to the positive terminal pin, of course, and the black wire to the negative pin. The alternative cut-down 10-cell holder simply solders to the supply pins on the PC board.

You should now be ready for the only slightly fiddly part of the assembly operation: attaching the PC board assembly to the rear of the lid/front panel.

This is only fiddly because you have to line up all of the extension wires from switches S2 and S3 and the two test terminals with their matching holes in the PC board, as you bring the lid and board together and also line up the spindle of switch S1 with its matching hole in the front panel.

This is actually easier to do than you'd expect though, so just take your time and the lid will soon be resting on the tops of the board mounting spacers. Then you can secure the two together using four 6mm-long countersink head machine screws.

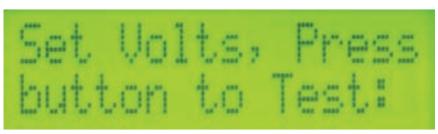
Now it is just a matter of turning the complete assembly over and soldering each of the switch and terminal extension wires to their board pads. Once they are all soldered, you can clip off the excess wires with sidecutters.

By the way, if you find this description a bit confusing, refer to the assembly diagram in Fig.5. This will make everything clear.

You can now fit six AA-size alkaline cells into the battery holder(s) and your new Capacitor Leakage Meter should be ready for its initial checkout.

Initial checkout

When you first switch on the power using S3, a reassuring glow should appear in the LCD display window – from the LCD module's backlighting. You should also be able to see the meter's initial greeting 'screen', quickly followed by an 'operational screen' – see display grab images below. If not, you'll need to use a small screwdriver to adjust contrast trimpot VR1, through the small hole just to the left of the LCD window, until you get a clear and easily visible display.



When you first turn the unit on, a welcome screen should greet you before it immediately switches over to the operational screen, telling you what to do...

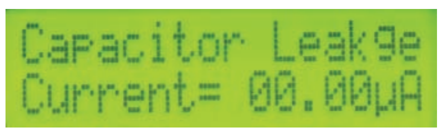
After a few seconds, the display should change to the meter's measurement direction 'screen', where it tells you to set the appropriate test voltage (using S1) and then press the button (S2) to make the test.

If you set the voltage and press the button at this stage, without any capacitor connected to the test terminals, you'll get a leakage current reading of '00.00µA'. This reading will remain on the display when you release the button, and it will stay on the display until you either turn off the meter's power using S3, or else connect a capacitor to the test terminals and press the test button again.

Assuming all has gone well at this point, your meter is probably working correctly. However, if you want to make sure, try shorting between the two test terminals using a short length of hookup wire. Then set S1 to the '100V' position, and press Test button S2. The meter reading should change to a value of around 9.9mA, representing the current drawn from the nominal 100V source by the 10kΩ current-limiting resistor and the 100Ω current shunt resistor inside the meter.

Don't worry if the current reading is a bit above or below the 9.9mA figure, by the way. As long as it's between about 9.2mA and 10.6mA (ie, ±0.7mA or ±7%), things are OK.

With the terminals still shorted together, you can try repeating the same test for each of the other six test voltage ranges of switch S1. You should get a reading of approximately 6.25mA on the 63V range, 4.95mA on the 50V range, 3.46mA on the 35V range, 2.48mA on the 25V range, 1.58mA on the 16V range and 99µA on the 10V range.



...where upon, the leakage current is displayed. Either this is an outstanding capacitor or none is connected!

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	1MΩ	brown black green brown	brown black black yellow brown
❏	1	270kΩ	red violet yellow brown	red violet black orange brown
❏	1	36kΩ	orange blue orange brown	orange blue black red brown
❏	1	33kΩ	orange orange orange brown	orange orange black red brown
❏	3	10kΩ	brown black orange brown	brown black black red brown
❏	1	8.2kΩ	grey red brown	grey red black brown brown
❏	1	5.6kΩ	green blue red brown	green blue black brown brown
❏	1	5.1kΩ	green brown red brown	green brown black brown brown
❏	2	3.6kΩ	orange blue red brown	orange blue black brown brown
❏	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❏	1	2.7kΩ	red violet red brown	red violet black brown brown
❏	2	2.4kΩ	red yellow red brown	red yellow black brown brown
❏	3	2.2kΩ	red red red brown	red red black brown brown
❏	1	2.0kΩ	red black red brown	red black black brown brown
❏	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❏	2	1kΩ	brown black red brown	brown black black brown brown
❏	2	270Ω	red violet brown brown	red violet black black brown
❏	1	200Ω	red black brown brown	red black black black brown
❏	1	180Ω	brown grey brown brown	brown grey black black brown
❏	1	150Ω	brown green brown brown	brown green black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	22Ω (0.5W)	red red black brown	red red black gold brown
❏	1	1Ω (0.5W)	brown black gold brown	brown black black silver brown

If the readings you get are close to these, your Capacitor Leakage Meter is working correctly.

This being the case, switch off the power again via S3 and then complete the final assembly by lowering the lid/PC board assembly into the case and securing the two together using the four small self-tapping screws supplied.

If you get readings which are significantly different to those above, there is obviously an error somewhere to be corrected. It is quite likely that one or more resistors in the 'string' from IC1 pin 5 to S1 is/are misplaced.

Using it

The Capacitor Leakage Meter is very easy to use, because literally all that you have to do is connect the capacitor you want to test across the test terminals (with the correct polarity in the case of solid tantalums and electrolytics: + to +, – to –), set selector switch S1 for the correct test voltage, then turn on the power (S3).

When the initial greeting message on the LCD changes into the 'Set Volts, press button to Test:' message, press and hold down test button S2.

What you'll see first off may be a reading of the capacitor's charging current, which can be as much as 9.9mA initially (with high value caps) but will then drop back as charging continues.

How quickly it drops back will depend on the capacitor's value. With capacitors below about 4.7µF, the charging may be so fast that the first reading will often be less than 100µA, with the meter having immediately downranged.

If the capacitor you're testing is of the type having a 'no leakage' dielectric (such as metallised polyester, glass, ceramic or polystyrene), the current should quickly drop down to less than a microamp and then to zero. That's if the capacitor is in good condition, of course.

On the other hand, if the capacitor is one with a tantalum or aluminium oxide dielectric, with inevitable leakage, the current reading will drop more slowly as you keep holding down the Test button.

In fact, it will probably take up to a minute to stabilise at a reasonably steady value in the case of a solid tantalum capacitor and as long as three minutes in the case of an aluminium electrolytic. (That's because these capacitors generally take a few minutes to 'reform' and reach their rated capacitance level.)

As you can see from the guide table earlier, the leakage currents for tantalum and aluminium electrolytics also never drop down to zero, but instead to a level somewhere between about 1µA and 4110µA (ie, 4.1mA), depending on both their capacitance value and their rated working voltage.

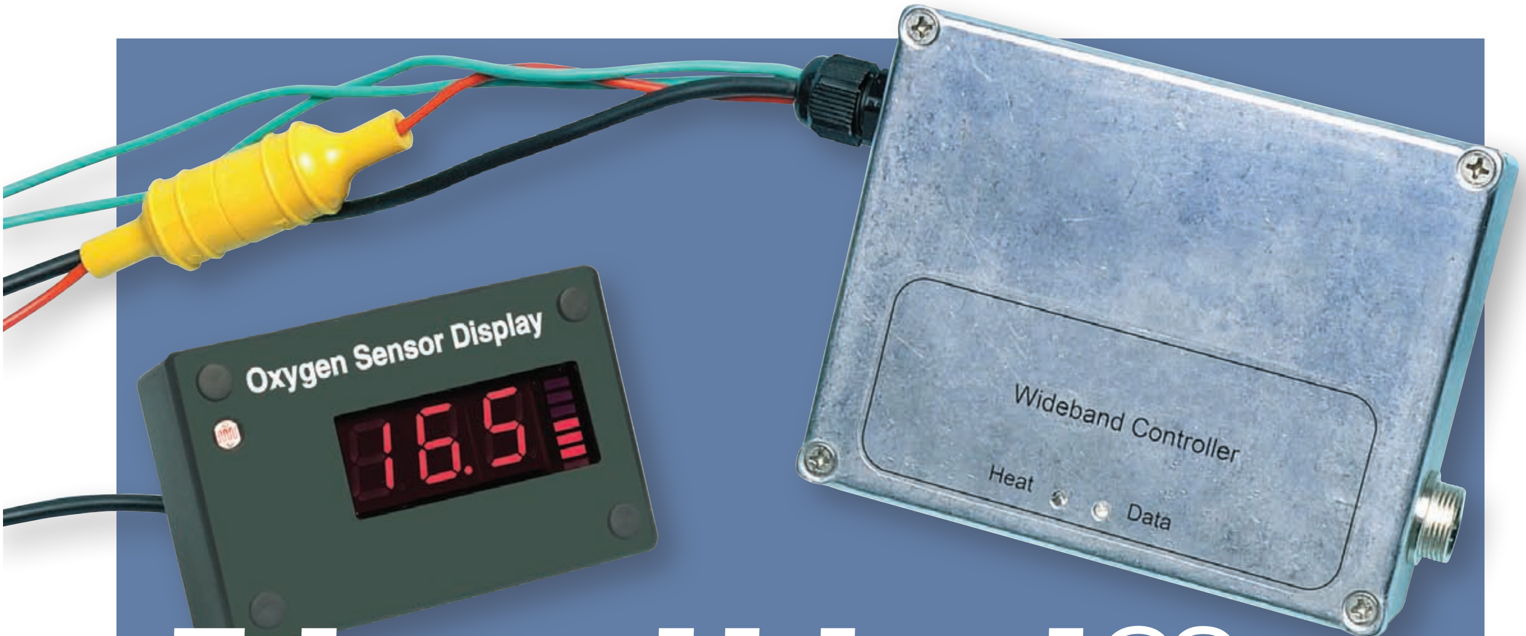
So with these capacitors, you should hold down the meter's test button to see if the leakage current reading drops down to the 'acceptable' level, as shown in the table (and preferably even lower). If this happens the capacitor can be judged to be 'OK', but if the current never drops to anywhere near this level then it should definitely be replaced.

What about low leakage (LL) electrolytics? Well, the current levels shown in the table are basically those for standard electrolytics rather than for those rated as low leakage. So when you're testing one which is rated as low leakage, you'll need to make sure that its leakage current drops well below the maximum values shown in the guide table. Ideally, it should drop down to less than 25% of these current values.

Finally

A final tip: when you're testing non-polarised (NP) or 'bipolar' electrolytics, these should be tested twice – once with them connected to the terminals one way around, and then again with them connected with the opposite polarity.

These capacitors are essentially two polarised capacitors internally connected in series, back-to-back. If one of the dielectric layers is leaky but the other is OK, this will show up in one of the *two* tests. ***EPE***



Using a wideband O2 sensor in your car – Part 1

For accurate measurement of air/fuel ratios

This Wideband Controller is intended to be used with a Bosch Wideband LSU4.2 oxygen sensor and last month's Wideband Sensor Display project to accurately measure air/fuel ratios over a wide range, from rich to lean. It can be used for precise engine tuning and can be a permanent installation in the car or a temporary connection to the tailpipe of the exhaust.

By JOHN CLARKE

Main features

- Accurate lambda measurements
- Precalibrated sensor
- S-curve output
- S-curve response rate adjustment
- Heat indicator LED
- Data indicator LED
- Engine started detection option
- Correct sensor heat-up rate implemented
- Heater over-current and under-current shutdown
- Optional fast heat-up if correct conditions are met

FOR precise engine tuning and modification, an accurate air/fuel ratio meter is a 'must have'. An engine that runs rich will use excessive fuel and cause air pollution, while an engine that runs too lean may be damaged.

Unfortunately, trying to diagnose engine mixture problems with the standard narrowband oxygen sensor fitted to all cars is quite difficult. While it is good enough to indicate the stoichiometric (ie, the air/fuel ratio at which there is just enough oxygen in the air to ensure complete combustion) mixture for use by the ECU (engine (or electronic) control unit), it is only accurate over a very narrow band; that it why it is called a narrowband sensor.

Typically, most engines should run with a stoichiometric mixture except when accelerating, when the mixture will be richer. Alternatively, during cruise conditions and engine overrun, the mixtures might go lean. In contrast, some engines run at stoichiometric continuously, regardless of engine load.

In control

So why do you need a controller for a wideband oxygen sensor? In brief, it's because a wideband sensor is very different from a narrowband sensor. In its most basic form, a narrowband sensor has only one wire and this is the sensor output. There is another connection via the metal frame of the unit. Other narrowband sensors have an internal heater, and these units may have three or four wires. Fig.1 shows a cross-section of a typical narrowband sensor.

By contrast, a wideband sensor has six wires. This is because it comprises a narrowband oxygen sensor, a heater and an oxygen ion pump, which diffuses oxygen ions into or out of the chamber that is monitored by the narrowband sensor.

Fig.2 shows the basic set-up for a wideband oxygen sensor installation. At left is the wideband sensor with its six leads, which are all connected to the wideband controller module. The controller module then has two outputs. First, there is an S-curve output, which simulates the output of a narrowband sensor, and can be used by the car's ECU to control fuel delivery to the engine. Second, there is a linear 0V to 5V output, which drives the *Wideband Display Unit* (as published in the October 2011 issue of *EPE*).

S-curve characteristic

The S-curve characteristic is shown in the graph of Fig.3, while the linear 0V to 5V output is shown in Fig.4. A voltage of 0V indicates a *rich* mixture (lambda 0.7) while 5V indicates a *lean* mixture (lambda 1.84). Lambda values for other voltages are calculated using the equation:

Lambda = V x 0.228 + 0.7

Note that a multimeter could be used to measure the wideband output voltage instead of the Wideband Display unit. However, most readers will want the combined bargraph and digital display of the latter.

Note also that the lambda value is simply the ratio of the air/fuel ratio compared to the stoichiometric air/fuel ratio. For petrol, it is generally accepted that the stoichiometric air/fuel ratio (the mass of air required to completely burn a unit mass of fuel) is 14.7:1, but this can drop to 13.8:1 when 10% ethanol is added.

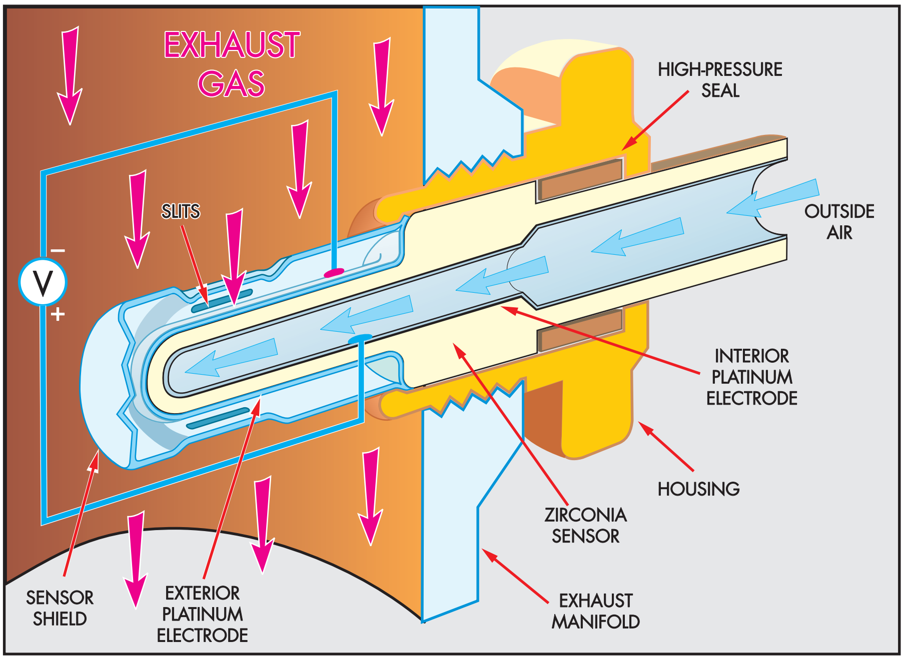


Fig.1: what's inside a narrowband zirconia oxygen sensor. It consists of a zirconia ceramic sensor element with thin platinum electrodes on both sides.

A lambda of 0.7 for petrol is the same as an air/fuel ratio of 0.7 × 14.7 or 10.29:1. Similarly, a lambda of 1.84 is an air/fuel ratio of 27.05:1.

The stoichiometric air/fuel ratio is typically 15.5:1 for LPG (liquid petroleum gas) and 14.5:1 for diesel. These values can differ, depending on the actual fuel composition, and for diesel it varies between the winter and summer fuels.

In fact, lambda is probably the best measure of air/fuel mixtures since it is a universal value and not dependent on the specific fuel.

Before we describe how a wideband sensor and its associated controller work, it is best to become familiar with the operation and characteristics of the narrowband sensor. If you are not sure how narrowband oxygen sensors work, we had a full description of this topic in the October 2011 issue of *EPE*.

Wideband sensor

As noted earlier, wideband sensor design is based on the narrowband zirconia oxygen sensor, but it includes a clever method to obtain a more linear response. This involves a second chamber incorporating a pump cell, where exhaust gas enters via the diffusion gap. The oxygen measurement is made within this diffusion gap. The pump cell moves oxygen ions into or out of the diffusion gap in order to maintain a stoichiometric measurement for the sensor cell.

If the measured mixture is lean, then the sensor cell detects excess oxygen.

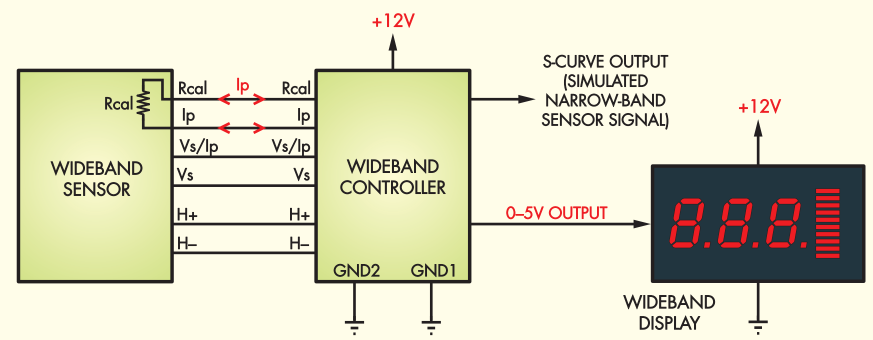


Fig.2: here's how the Wideband Controller is used with a wideband oxygen sensor, and with the Wideband Display described in October 2011 to provide accurate air/fuel mixture monitoring. As shown, the Wideband Controller has both a wideband output and a narrowband (S-curve) output.

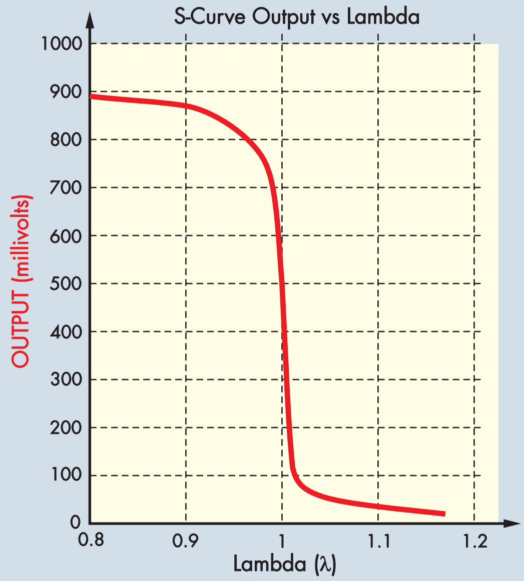


Fig.3: the S-curve output from the Wideband Controller simulates a narrowband sensor output (the response follows the Bosch LSM11 narrowband sensor curve). Note the steep slope in the curve during stoichiometric (ie, lambda = 1) conditions.

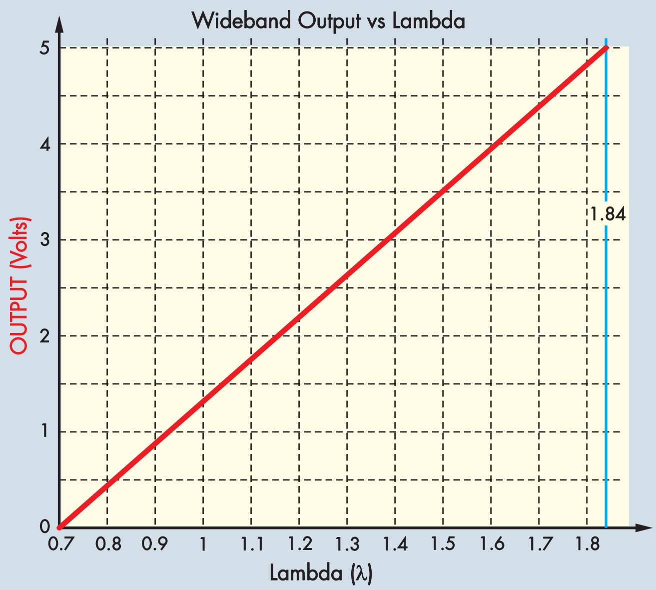


Fig.4: the wideband output from the Wideband Controller is linear with respect to lambda values from 0.7 to 1.84. The resulting signal is ideally displayed on the *Wideband Display Unit* from the October 2011 issue of *EPE*.

The pump cell then drives oxygen ions out of the diffusion gap until the sensor cell measures a stoichiometric mixture.

Conversely, if the mixture is rich, oxygen ions are pumped from the surrounding exhaust gas into the diffusion gap until the sensor cell reaches its stoichiometric measurement. As a result, the current applied to the pump cell can be either positive or negative, depending on whether oxygen is pumped into or out of the diffusion gap.

At this point, it may seem as though the oxygen pump actually tricks the narrowband sensor into 'thinking' that the mixture is stoichiometric. This might seem to defeat the purpose of having the narrowband sensor, but bear with us; all will be revealed.

Wideband controller

Fig.5 shows the basic scheme for a wideband controller. Here, Vs is the output voltage from the oxygen sensor cell, while Ip is the current into or out of the pump cell. At the stoichiometric point, Vs is 450mV, and this is compared against a 450mV reference.

If Vs is higher than the 450mV reference, the mixture is detected as 'rich' and the Vs sense comparator output goes high. This 'informs' the controller that Ip needs to change, to pump oxygen ions into the diffusion gap in order to regain a stoichiometric measurement.

Similarly, if Vs is lower than the 450mV reference, the exhaust mixture is detected as 'lean' and the comparator output goes low. As a result, the controller adjusts Ip to pump oxygen out of the diffusion gap.

Note that if there is no Ip control, the sensor cell behaves like a standard narrowband sensor with an output voltage above 450mV for rich mixtures and below 450mV for lean mixtures. However, with current control, the pump current is adjusted to maintain a 450mV reading from the sensor cell.

Variations in the sensor cell voltage indicate the change in mixture in either the rich or lean direction, while the Ip current shows whether the mixture is actually rich or lean. A negative Ip current indicates a rich mixture and a positive current a lean mixture. The amount of current indicates the lambda value.

Fig.6 plots oxygen content against pump current Ip for lean mixtures.

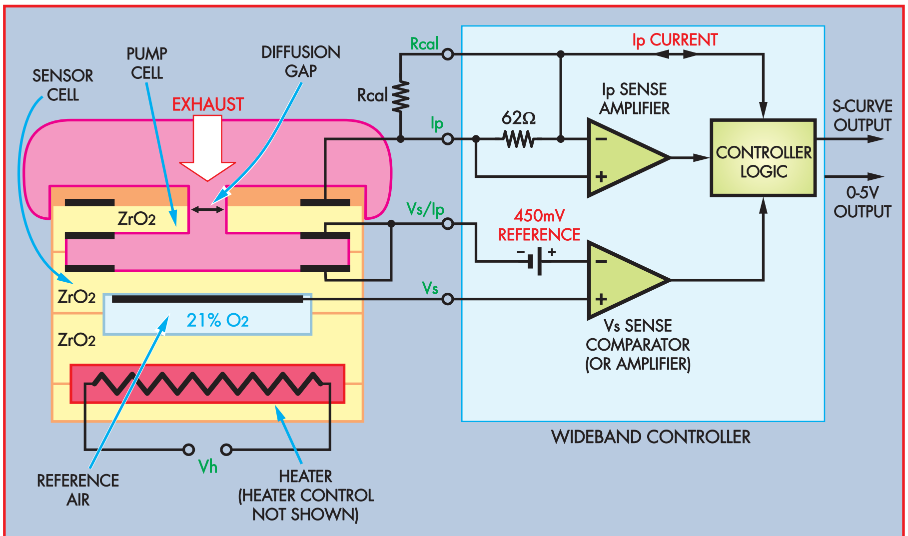
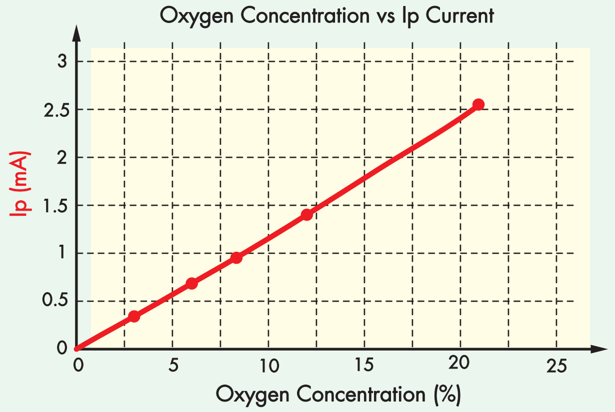


Fig.5: the basic scheme for a wideband oxygen sensor and its associated controller circuit.

Note that the graph is almost linear. The controller converts Ip current to an equivalent lambda value for display on the Wideband Display Unit.

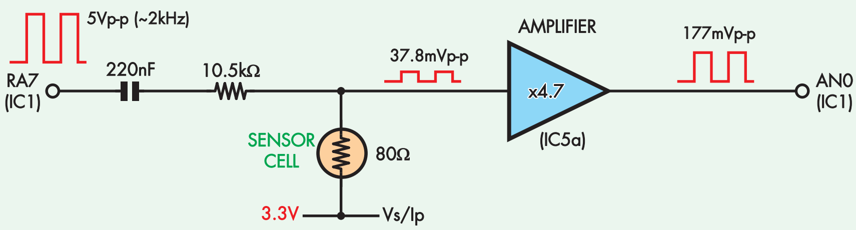
The Ip current is sensed by measuring the voltage across the 62Ω 1% resistor (in parallel with Rcal). However, during the manufacture of each sensor, the actual resistor used by Bosch is 61.9Ω (a 0.1% tolerance value from the E96 range). Rcal is trimmed so that the voltage across this resistor, measured against lambda, is the same for each sensor. In fact, Rcal can vary from 30Ω to 300Ω, depending on the characteristics of the individual sensor. Hence, the value for Ip shown on the vertical axis of Fig.6 (and Fig.9 which we will come to later) is not the total pump current.

In these graphs, Ip only relates to the voltage across the 62Ω resistor. So, while Fig.6 shows Ip varying between zero and about 2.55mA, the actual range could vary from 0mA to 3.07mA if Rcal is 300Ω, or up to about 7.8mA if Rcal is 30Ω. This is really only of academic interest, but we mention it for the sake of completeness. The same convention is used by Bosch in its application literature on the LSU4.2 wideband oxygen sensor.



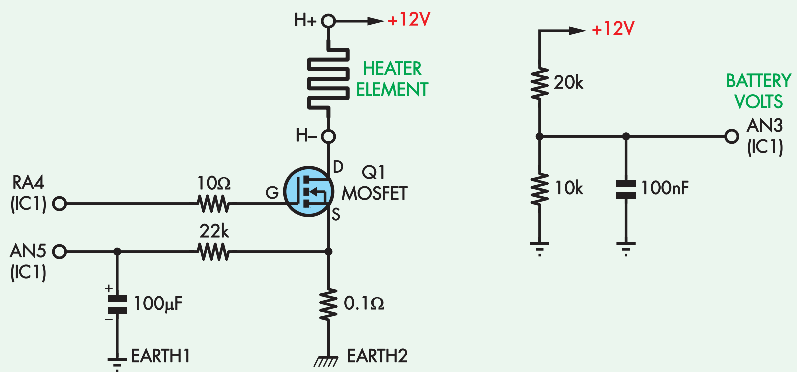
Oxygen concentration	Measured Ip
0.0%	0.00mA
3.0%	0.34mA
6.0%	0.68mA
8.29%	0.95mA
12.0%	1.40mA
20.9%	2.55mA

Fig.6: this graph plots the oxygen concentration against the Ip current for the lean measurement region where there is 0% or more remaining oxygen. Note that the current with respect to oxygen content is almost linear. The marked points on the graph have the values shown in the table.



SENSOR CELL IMPEDANCE MEASUREMENT

Fig.7: the temperature of the sensor cell is monitored by measuring its impedance using the circuit configuration shown here.



HEATER CONTROL

Fig.8: the heater element is controlled by a MOSFET that switches the power on and off. Temperature control is achieved by driving the MOSFET with a PWM (pulse-width modulation) signal to vary its duty cycle.

Heater element control

Apart from controlling the oxygen pump, the Wideband Controller also controls a heater element so that the sensor's temperature is maintained at approximately 750°C. In fact, the sensor doesn't provide accurate readings until this temperature is reached.

There is no temperature probe within the sensor, and so the temperature is measured by monitoring the impedance of the sensor cell. This has an impedance above 5kΩ at room temperature, falling to 80Ω at 750°C.

We measure the impedance of the sensor cell by applying an AC signal to it. Fig.7 shows the circuit arrangement. A 5Vp-p (5V peak-to-peak) AC signal is applied to the sensor cell via a 220nF capacitor and a 10.5kΩ resistor.

The capacitor ensures that the sensor receives AC with no DC component, and the resistor forms a voltage divider in conjunction with the impedance of the sensor cell. When the sensor cell is 80Ω, the voltage swing across the sensor cell is 37.8mVp-p.

Amplifier IC5a has a gain of 4.7, so its output is 177mVp-p. The microcontroller (IC1) maintains that value by controlling the heater current.

How the heater element is controlled is shown in Fig.8. The gate (G) of MOSFET Q1 is driven with a pulse-width modulated (PWM) signal to control the heater current over a wide range.

The MOSFET current is monitored via a 0.1Ω resistor in series with its source (S). The voltage across this resistor is filtered via a 22kΩ resistor and 100µF filter capacitor, and fed to the microcontroller (input AN5).

Should the heater become disconnected or open circuit, the lack of current will be detected, and this will switch off the Wideband Controller functions. Similarly, if the heater current is excessive, the controller will switch off the heater.

Note that when the Wideband Controller is first switched on, the heater must heat up gradually to minimise

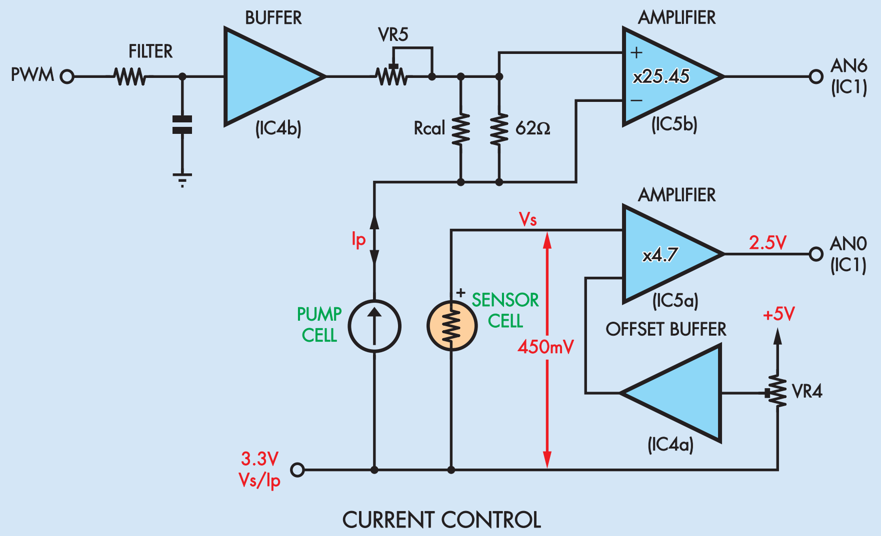


Fig.9: this diagram shows the general arrangement for the pump sensor control and the sensor cell measurement. Buffer stage IC4b supplies current to the pump cell via trimpot VR5 and the paralleled R_{cal} and 62Ω resistors. The other side of the pump cell connects to a 3.3V supply (formed using buffer stage IC2b and set by trimpot VR3 – see Fig.12).

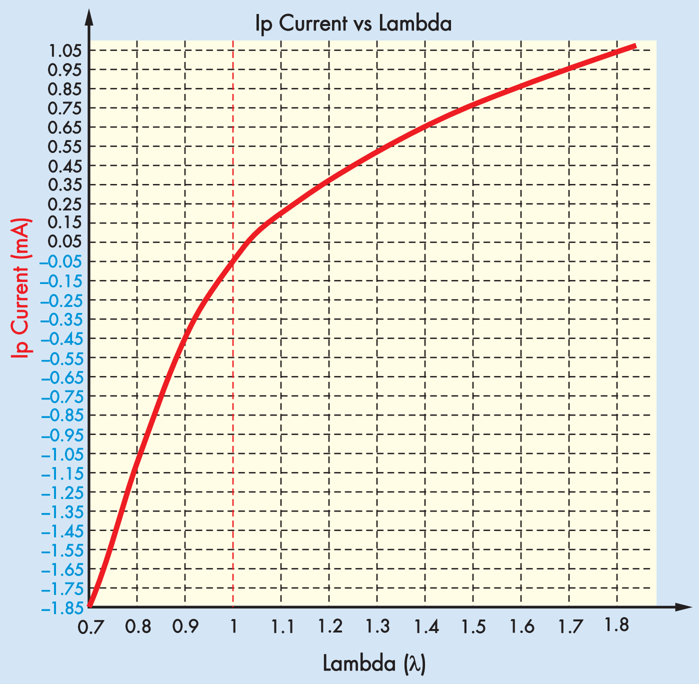


Fig.10: this graph plots the Ip current versus lambda for the wideband sensor. The curve in the lean region (lambda = 1 to 1.84) was developed from the oxygen concentration graph shown in Fig.5 and the equation *((Oxygen percentage/3) +1)/(1 – 4.76 × Oxygen percentage)* to give a 20-step, piecewise-linear graph. The intermediate values were then calculated by interpolating between adjacent calculated values. For the rich region, the 4-step graph provided by Bosch is used.

thermal shock to the ceramic sensor. Our circuit uses an initial effective heater voltage of 7.4V that rises at a rate of 73.3mV every 187.5ms. This is 0.390V/second and just under the maximum rate of 0.4V/s specified by Bosch. The initial effective heater voltage depends on the sensor temperature and ranges from 7.4V at – 40°C to 8.2V at 20°C. The Wideband Controller always starts at the – 40°C value.

For a permanently installed sensor, heating can begin from a higher initial effective voltage of 9V at –40°C. This is provided that the sensor is installed in accordance with the mounting requirements specified by Bosch. Using this higher effective heater voltage at start up will shave three seconds off the preheat period. This faster heat up requires a software change, which will be discussed next month.

Note that we use the term 'effective heater voltage' rather than 'voltage' because the effective heater voltage is the RMS value of the pulse waveform applied by the MOSFET. In order to monitor the heater voltage, we also have to monitor the battery voltage, which can be from around 12V before the engine starts up, to more than 14V when the engine is running.

As shown in Fig.8, the battery voltage is measured using a voltage divider comprising 20kΩ and 10kΩ resistors, together with a 100nF capacitor to filter out voltage spikes.

To sum up, the impedance of the sensor cell is constantly monitored, and as soon as it reaches 80Ω, the preheat is complete and power to the heater is controlled to maintain this value. Once the sensor has reached its operating temperature (750°C), the pump control circuit begins to operate.

Pump sensor control

The general arrangement for the pump sensor control is shown in Fig.9. Buffer op amp IC4b supplies current to one side of the pump cell via trimpot VR5 and the paralleled Rcal (inside the wideband sensor) and 62Ω resistors. The other side of the pump cell connects to a 3.3V supply.

When the output of IC4b is at 3.3V, there is no current through the pump cell. For positive current through the pump cell, IC4b's output goes above 3.3V. Conversely, when IC4b's output is below 3.3V, the pump cell current is negative. IC4b can swing between 5V and 0V, to allow for the current range required for the 1.84 to 0.7 lambda extremes of measurement.

The pump cell current (Ip) is monitored using op amp IC5b, which has a gain of 25.45.

A graph of Ip versus lambda for the wideband sensor is shown in Fig.10. The curve in the lean region (lambda from 1 to 1.84) was developed to give a 20-step linear graph from the oxygen concentration graph shown in Fig.6 and the equation:

((Oxygen% ÷ 3) +1)/(1 – 4.76 x Oxygen%)

A look at narrowband oxygen sensors

Narrowband oxygen sensors are installed on most modern cars. They are used to monitor the air/fuel ratio from the engine exhaust, but they really are only accurate for measuring the stoichiometric mixture value. The stoichiometric mixture is where there is just sufficient oxygen for the whole of the fuel to be completely burnt.

Under these conditions, a car's catalytic converter can work best at converting combustion byproducts to less harmful compounds. Carbon monoxide (CO) is converted to carbon dioxide (CO_2), unburnt hydrocarbons to carbon dioxide (CO_2) and water (H_2O) and nitrous oxide (N0) to nitrogen (N_2).

When a vehicle is running with a stoichiometric mixture, the engine management unit is constantly monitoring the oxygen sensor and altering the fuel so the mixture remains constant. The sensor output under this controlled condition tends to rise to around 480mV as the mixture goes ever so slightly rich before the ECU reduces fuel so that the mixture becomes very slightly lean at about 420mV. The sensor output therefore oscillates about the stoichiometric output at 450mV. Under these oscillations the system is said to be in closed loop.

Richer or leaner mixtures from stoichiometric result in the sensor output voltage going much higher or lower than 450mV. However, the response from the sensor is very steep at stoichiometric conditions, such that the sensors output can range from 150mV through to about 750mV, with very little change in the mixture. The output response for a typical narrowband sensor is shown in Fig.3.

For other mixtures (ie, when it is rich or lean), the sensor output can only be used as a guide to the actual air/fuel ratio. For rich mixtures, there is unburnt fuel in the exhaust and a narrowband sensor produces a voltage that can vary from typically 0.75V to 0.9V, depending on the fuel mixture. For lean readings, where there is excess oxygen in the exhaust, the sensor output will generally be below 150mV.

When a vehicle is running in the rich or lean region, the control is said to be open loop – where the mixture is not controlled. Rich mixtures are often set to provide improved acceleration response, while lean mixtures are often initiated during cruising to reduce fuel consumption.

Additionally, the response within the rich region is very temperature dependent, and can vary by several hundred millivolts between when the sensor is cold compared to when heated by the exhaust. Some sensors include a heater element, but unless it is controlled to maintain a constant temperature, the mixture readings are inaccurate.

For accurate rich and lean readings off the stoichiometric point, some other way of measuring the mixture is required. The Bosch LSM11 narrowband 'lean' sensor provides a more accurate response to air/fuel mixtures than most other narrowband sensors, and has been called a wideband sensor. However, this sensor is not a true wideband sensor and has the characteristic steep response curve at stoichiometric.

Fig.1 shows how a narrowband zirconia oxygen sensor is made. It's typically about the size of a spark plug and is threaded into the exhaust system so that the sensor is exposed to the exhaust gasses. The assembly is protected using a shield that includes slots so that the exhaust gasses can pass through into the sensor.

The sensor itself is made from a zirconia ceramic material that has a thin layer of porous platinum on both sides. These platinum coatings form electrodes to monitor the voltage produced by the zirconia sensor as the exhaust gas passes through it. The device operates by measuring the difference in oxygen content between the exhaust gas and the outside air. The oxygen content of the air (about 20.9%) serves as the reference. In operation, a voltage is produced between the electrodes because the zirconia sensor has a high conductivity for oxygen ions at high temperatures.

For the rich region, the 4-step graph provided by Bosch is used.

Another calculation is made to convert the lambda value to the voltage required at the wideband output, as shown in Fig.4. Similarly, the lambda value is converted to an S-curve response for the narrowband S-curve output. This curve is shown in Fig.3.

A further complication with the pump current is that it is dependent on exhaust back pressure. Fig.11 graphs the change in Ip versus pressure. This can be matched with the Lambda *vs.* Ip graph (Fig.10) to determine the effect on the readings. Note that exhaust pressure does not have an effect on stoichiometric readings because the Ip current is zero.

Op amp IC5a monitors the sensor cell voltage. Its gain is 4.7. Trimpot VR4 is used to provide an offset voltage, which is buffered by IC4a. VR4 is

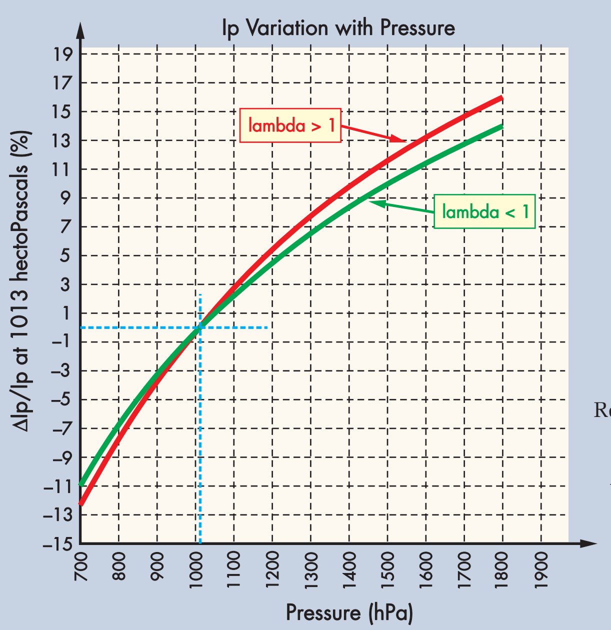


Fig.11: this graph shows how the Ip current changes with pressure. This can be used in conjunction with the Ip Current *vs* lambda graph (Fig.10) to determine the effect on the readings.

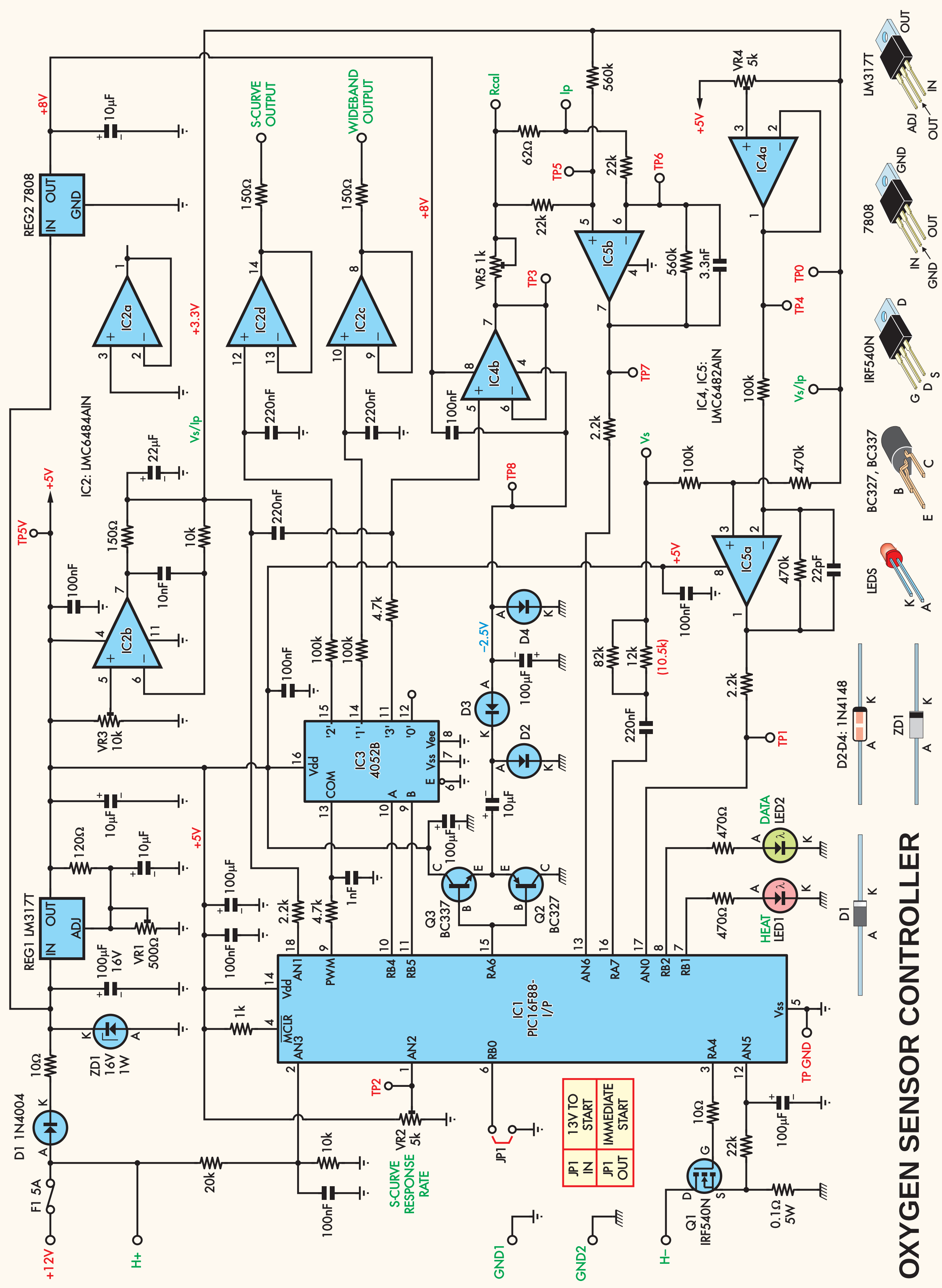


Fig.12: the full circuit uses microcontroller IC1, several CMOS op amps (IC2, IC4 and IC5) and a multiplexer (IC3). The microcontroller monitors and controls the wideband oxygen sensor and drives the Wideband Display Unit. It also provides a narrowband (S-curve) signal output.

set so that IC5a's output is 2.5V when the sensor cell voltage is 450mV. The microcontroller monitors this voltage and varies pump current accordingly.

LED indicators

Two LED indicators (see Fig.12 – Heat and Data) show the operation of the wideband sensor. During preheat, the Heat LED is continuously on until the sensor is up to operational temperature (750°C). After that, the Heat LED flashes once a second to indicate normal control. If the LED is not illuminated, then the sensor temperature is above 750°C, which can occur for very high exhaust gas temperatures.

The Data LED flashes each time the wideband output is updated. With constant data updates, this LED will be constantly lit. However, it may extinguish during an exhaust gas mixture change before current control is restored.

If this LED flashes at a regular 1Hz, then the data is in error. This could be because the lambda reading is over-range or the heater has become disconnected. In this later case, the wideband output defaults to a lambda value of 1 and the S-curve output is set at 450mV.

Circuit description

The full circuit diagram for the *Oxygen Sensor Controller* is shown in Fig.12 and is based on a PIC16F88-I/P microcontroller (IC1). Its features include a 10-bit PWM output and 10-bit analogue-to-digital conversion. It runs with an internal 8MHz clock oscillator.

The op amps used in the circuit are special. We have specified one LMC6484AIN quad op amp (IC2) and two LMC6482AIN dual op amps (IC4 and IC5). These have a typical input offset of 110µV; a high input impedance of more than 10TΩ (teraohms); a 4pA input bias current; an output to within 10mV of the supply rails with a 100kΩ load and a wide common-mode input voltage range that includes the supply rails.

An LM317T adjustable regulator (REG1) supplies 5V to the whole circuit except for IC4. VR1 is adjusted so that REG1's output is exactly 5.00V.

The battery voltage is measured at the AN3 (pin 2) input of IC1 via a 20kΩ and 10kΩ voltage divider connected between the 12V input and 0V. This divider results in a maximum of 5V at the AN3 input for a battery voltage of 15V. 5V is the upper limit for analogue-to-digital conversion by IC1 to the maximum 10-bit digital value. The 15V converts to a digital value of 1023, while 8V converts to a value of 545.

Trimpot VR3 provides the reference voltage of 3.3V, which is buffered by op amp IC2b. This op amp drives one side of the pump cell, the Vs/Ip connection, via a 150Ω resistor, which isolates the op amp output from the 22µF capacitor, which is included to remove ripple on the Vs/Ip supply reference. A 10kΩ resistor provides DC feedback, while the 10nF capacitor is included to prevent instability.

Multiplexer drive signals

IC1 delivers a 7.843kHz PWM signal to the common input pin of the 4052 multiplexer IC3 via a 4.7kΩ resistor. The 1nF capacitor to ground provides some filtering of this signal, removing the high-frequency components of the square-wave above about 33kHz. This reduces crosstalk between the three output channels at pin 11, pin 14 and pin 15.

IC2d provides the DC voltage, after the PWM signal is filtered, to drive the S-curve output. IC2c provides the wideband (0V to 5V) output and IC4b provides the pump cell drive.

Let's look at this in more detail. The micro (IC1) drives the A and B inputs, pin 9 and pin 10 of IC3 to select its output. With both A and B at 0V, the selected output is '0' (pin 12) which is not connected. However, this '0' output is selected each time the duty cycle of the PWM signal is changed to suit the three selected outputs at pins 11, 14 and 15. So the switching sequence for IC3 is 0, 1, 0, 2, 0, 3 and so on.

Each output has a low-pass filter to convert the PWM signal to a DC voltage,

Specifications

Power requirements: 11V to 15V, nominally 12V at 5.7A peak at start up maximum. Typically 16W when heated.

Sensor ageing: lambda at 1.70 ±0.15; lambda at 0.8 ±0.04.

Reading accuracy: ~1%.

Measurement range: 0.7 (rich) to 1.84 (lean) lambda.

Sensor heating: begins at an effective 7.4V and ramps up at 73.3mV/187.5ms and is equivalent to 390mV/s.

Heat-up period: < 22s from initial 20°C.

Heater over current: 4A.

Heater open-circuit detection: if current is less than 390mA at initial power up.

Heater PWM frequency: during ramp up, 15.26Hz; during heat control >2Hz.

Heater maximum effective voltage: 12V after initial preheat and at 13V for <1 minute.

Sensor temperature: Controlled at ~750°C using the 80Ω at 750°C impedance of the sensor cell for the measurement.

Sensor cell measurement: AC drive at 1.953kHz and 473µA.

Sensor cell DC loading: <10µA.

Wideband output: Linear 0V to 5V output for 0.7 to 1.84 lambda.

S-curve output: simulates a 0.8 to 1.17 range following the Bosch LSM11 sensor curve.

S-curve response: Adjustable from the wideband response rate to 1.2s more than the wideband response rate.

Reading variation with pressure: see graph of change in Ip versus pressure.

Reading response: 250ms to a 5% change in oxygen.

WHERE TO FIND DATA

- Data for the LSM11 and the LSU4.2 sensors mentioned is available. For Bosch LSM11 and Bosch LSU4.2 sensors, see:
  www.bosch.com.au/content/language1/downloads/Section_D.pdf
- Further data on the Bosch LSU4.2 is at:
  www.ontronic.com/products/doc/Bosch_LSU_4_2.pdf

All the parts, except for the oxygen sensor and its input socket are mounted on a single PC board, which fits inside a diecast case. The full assembly details are in Part 2 next month

and this is buffered using the respective op amps.

IC2c and IC2d buffer the voltages for the wideband lambda output and S-curve signals respectively, while IC4b buffers the voltage for the pump cell current. The 220nF filter capacitors at the inputs to these op amps store the voltage during the periods when the respective outputs from IC3 are not selected.

Extra supply rails

IC4b is a special case because its output is required to swing from 0V to 5V to drive the pump cell. To ensure this, IC4's positive supply rail needs to be more than +5V and the negative rail needs to be less than 0V.

Hence, REG2 provides 8V and a negative supply is produced using transistors Q2 and Q3, diodes D2 and D3, and the associated capacitors. The circuit is driven by the RA6 output of IC1, which generates a 1.953kHz square wave signal. Transistors Q2 and Q3 buffer this signal to drive the diode pump consisting of D2 and D3. The resulting negative supply is –2.5V.

This is the Bosch LSU4.2 wideband sensor that's used in conjunction with the Wideband Controller

This means that op amp IC4 is not operating with symmetrical supply rails, but that doesn't matter; the supply rails are adequate to guarantee that IC4b can swing its output positive and negative as required by IC1.

Diode D4 is there to hold the negative supply rail at +0.6V when the negative supply generator is not working, ie, when IC1 is not in circuit.

Op amp IC5b is connected as a differential amplifier to monitor the voltage across the paralleled 62Ω and Rcal resistors. Its gain of 25.45 is set by the two sets of 560kΩ and 22kΩ resistors at pin 5 and pin 6, respectively. A 3.3nF feedback capacitor rolls off high frequencies and prevents amplifier instability.

The output of IC5b is referenced to the Vs/Ip voltage (+3.3V) by the 560kΩ resistor between its pin 5 input and the output of op amp IC2b. As a result, when 0V is across the 62Ω resistor, IC5b's output sits at 3.3V.

Note that the Vs/Ip voltage is continuously monitored by the AN1 input (pin 18) of IC1.

Op amp IC5a monitors the sensor cell voltage, Vs. As already noted, IC5a is set so that when Vs is at 450mV, its output is 2.5V. To do this, VR4 provides an offset voltage which is buffered using op amp IC4a. This means that IC5a can swing symmetrically above and below this level to drive pin 17, the AN0 input of IC1.

Link settings

Link JP1 selects the in-car installation mode. This requires that the engine starts before any electrical heating of the sensor begins. This ensures that any water condensation in the sensor is blown out before electrical heating. This prevents thermal shock and possible damage to the sensor.

Basically, the battery voltage must rise above 13V before heating begins. 13V indicates that the engine has started and the alternator is running to charge the battery. Once heating begins, the battery voltage can fall below 13V without switching off the heater.

Without link JP1 installed, the heater is driven as soon as power is applied. This is suitable when the wideband controller is used as a portable air/fuel ratio instrument. This means that the sensor MUST be protected from moisture ingress and from physical shock when not in use.

MOSFET Q1 drives the heater with a DC voltage derived from the PWM signal delivered from the RA4 output, pin 3, of IC1. Its source current is monitored via the AN5 input, pin 12.

Note that the circuit uses two earths. One earth (GND2) is for the heater and the other (GND1) is for the rest of the circuit. These two grounds are connected to the car chassis via separate wires. Without this separate earthing, the switching current applied to the heater would cause inaccuracies in the measurements of voltage and current and for the wideband output.

LED1 and LED2 are driven via the RB1 and RB2 outputs of IC1 via 470Ω resistors. The $\overline{\text{MCLR}}$ input to IC1 is the reset input, and ensures IC1 is reset on power up.

The S-curve output response rate is set using trimpot VR2. This can apply a voltage ranging from 0V to 5V on AN2 (pin 1) of IC1, corresponding to no delayed response when set at 0V, through to a 1.25s response at 5V.

That completes the circuit description. Next month, we will move onto construction and describe the setting-up procedure.

Strange but true

TechnoTalk

Mark Nelson

Couple an insatiable appetite for reading and an uncontrollable lust for sharing out-of-the-ordinary knowledge and you've summed up our correspondent Mark Nelson. Just read on and enjoy having your mind expanded (or your intelligence insulted) by his oddball discoveries.

BACK in the 1980s, there were rumours that someone living near the Crystal Palace television transmitter in south London had lined his loft with wire netting and was harvesting some of the one megawatt of radio frequency power. Whether this was feasible I don't know (maybe you do), but it sounds distinctly 'iffy' to me and not something that I'd admit to others.

Researchers from the Georgia Institute of Technology in America have no such qualms, however, and are 'stealing with pride' as people say. What they have done is to discover a way of capturing and harnessing energy transmitted not just from television towers but many other radio systems too.

And they use paper instead of wire netting. 'There is a large amount of electromagnetic energy all around us, but nobody has been able to tap into it,' claims Manos Tentzeris, a professor in the Georgia Tech School of Electrical and Computer Engineering, who is leading the research. Of course, energy harvesting is not exactly a novel concept, but the technique that Tentzeris and his team are using to collect ambient electricity probably is. Their goal is to make self-powered wireless devices that could be used for chemical, biological, heat and stress sensing for defence and industry; radio-frequency identification (RFID) tagging in manufacturing and shipping; plus all manner of other monitoring tasks.

Flea power it's not

The team's scavenging technology collects radio frequency energy in frequencies from FM radio (100MHz) all the way up to the radar bands at 15GHz, rectifying it from AC to DC and then storing it in capacitors and batteries. Their experiments in TV frequencies have already yielded power amounting to hundreds of microwatts, and multi-band systems are expected to generate one milliwatt or more. That amount of power is enough to operate many small electronic devices, including a variety of sensors and microprocessors.

By combining energy-scavenging technology with super-capacitors and cycled operation, they expect to power devices requiring 50mW and more. Already, the researchers have successfully operated a temperature sensor using electromagnetic energy captured from a television station that was half a kilometre distant.

The scavenging device could be used by itself or in tandem with other generating technologies. For example, scavenged energy could assist a solar element to charge a battery during the day. At night, when solar cells don't provide power, scavenged energy would continue to increase the battery charge or prevent discharging.

Paper thin

What's also novel is the way the researchers are combining the sensor, antenna and energy-scavenging capabilities into a single unit, printed using inkjet technology onto paper or flexible paper-like polymers. The result is a paper-based wireless sensor that is self-powered, low-cost and able to function independently almost anywhere.

The inkjet device used to print the electrical components and circuits is standard issue, but using what Tentzeris calls 'a unique in-house recipe' containing nanoparticles of silver and/or other materials in an emulsion. This approach enables the team to print not only RF components and circuits, but also novel sensing devices based on such nanomaterials as carbon nanotubes.

Rare earth shortage

Nothing to do with the Motown singers, but the seventeen types of REM (rare earth metal) that play such an important role in high-tech electronics applications. Uses for REMs include the new super-power magnets, fluorescent and mercury vapour lamps, lasers and masers, ceramic capacitors, nuclear batteries, X-ray machines and high quality alloys such as vanadium steel.

Although called rare earths, they are not actually scarce and are relatively plentiful in the Earth's crust. For example, cerium, used in CRTs, fluorescent lamps and gas mantles, is in fact the 25th most abundant element. All the same, rare earth elements are generally pretty dispersed in their occurrence and are seldom found in concentrated and economically exploitable forms.

But what's the big deal?

Precisely this: rare earths have just got rarer, as trade journal *EE Times* reports. China, the world's dominant supplier, is tightening restrictions on production and cutting the already short-supply exports by a third. As a result, rare earth prices are sky-rocketing in a market where supply can only meet about 40 percent of the demand outside China.

This will affect the cost-effectiveness of many electronic products. Finite resources in China, it is reported, means that resources of 'heavy' rare earths will last only another 15 years or so at current rates of production and use. Meanwhile, China is stockpiling its own supplies and limiting exports. The country has also put a ban on new mining licences for rare earths.

On the positive side, one bright spot amid the gloom is the seeming paradox that these price hikes could accelerate the transition to solid-state lighting – or delay the decline of incandescent lamp bulbs. That's because much less phosphor is needed to coat the inside of an LED than a fluorescent bulb. *EE Times* reports that a blue LED can be used to pump green silicate phosphors mixed with red and yellow nitride phosphors to make white light, a process using comparatively little rare earth minerals.

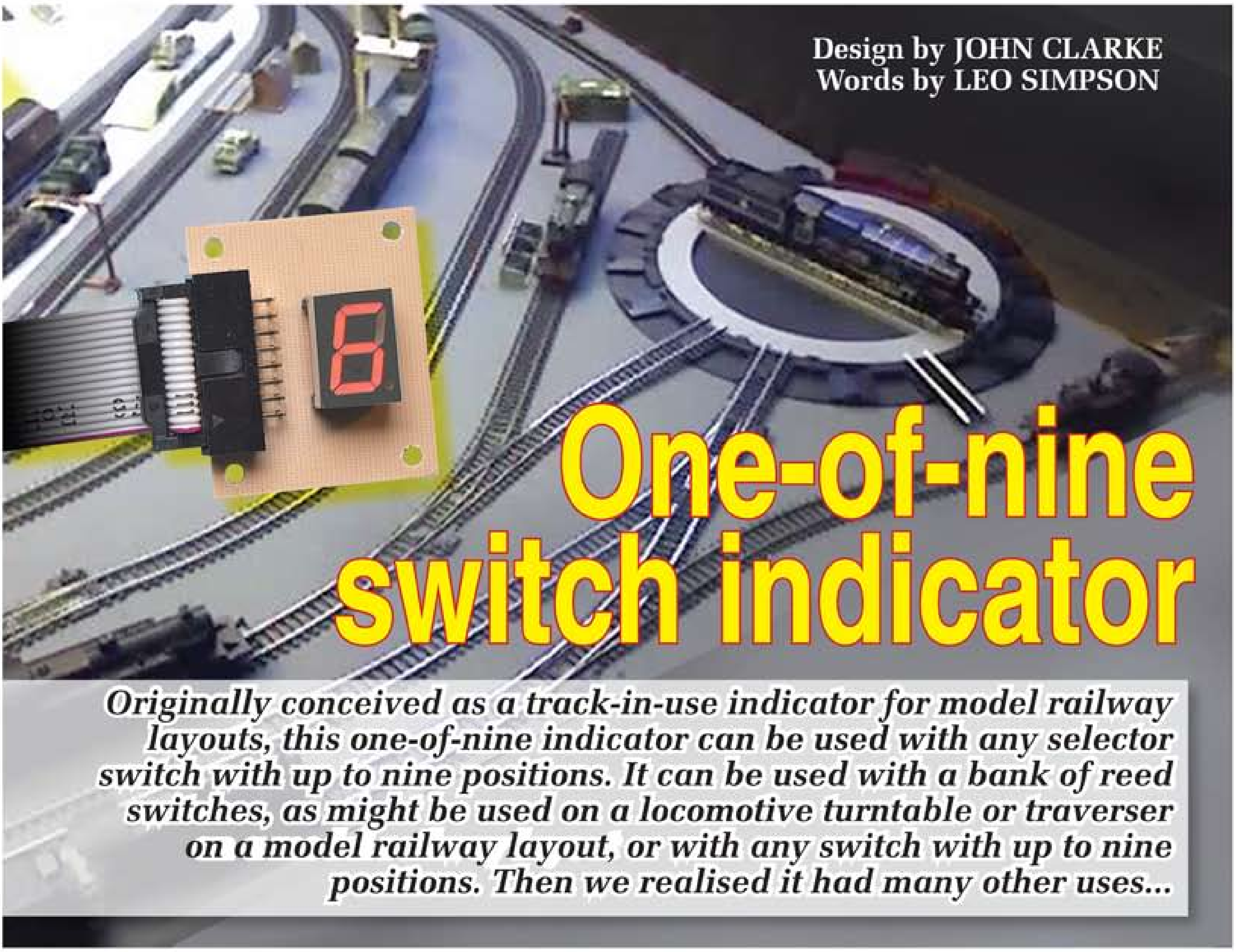
Inflatable antennas

This story, which sounds rather like hot air, is entirely matter-of-fact. In devastated areas, satellites provide the only means of instant communication for the emergency and rescue services. When tornados struck the south-eastern United States earlier this year, all kinds of communication links (telephone, Internet and cellular radio) were hit, with many areas suffering power disruption for nearly a week.

The 'magic bullet' used by the emergency services was an inflatable antenna made by the US company GATR Technologies. Their product is an ultra-portable all-in-one communications terminal that can replace large antennas or boost the gain of small dish terminals.

The lightweight dish antenna is housed inside a unique inflatable ball that is quick and easy to set up (inflated, anchored, and on-satellite in under 30 minutes). Remarkably, these terminals can be packed into two transit cases weighing less than 100lb each, or a single case/or backpack.

It strikes me that it would be ideal for amateur radio field day outings. No prices are quoted on the **gatr.com** website, but you can bet they are not cheap!



Design by JOHN CLARKE
Words by LEO SIMPSON

One-of-nine switch indicator

Originally conceived as a track-in-use indicator for model railway layouts, this one-of-nine indicator can be used with any selector switch with up to nine positions. It can be used with a bank of reed switches, as might be used on a locomotive turntable or traverser on a model railway layout, or with any switch with up to nine positions. Then we realised it had many other uses...

ANY railway modeller will be familiar with the problem: you have a locomotive turntable or switch-yard and you are never sure which track is actually selected, unless you go and have a close look.

Or you could have the same problem with a traverser which selects rolling stock storage tracks. With a locomotive turntable you may well be sure that a track has been correctly 'indexed', but you still don't know which one has been selected. The solution to that problem is a reed switch associated with each output track, and a magnet on the turntable to activate each reed.

The bank of nine (or less) switches is wired effectively as a single-pole rotary switch, and then can be coupled to a single-digit display. From there, the concept can be applied to any situation where a rotary switch is used, with one or two provisos which we will come to later.

Normally-open switches

More specifically, this Switch Indicator is designed to operate with normally-open switches, such as reed switches. With no switches closed, the single-digit display will show zero (0). With a switch closed, the display will show the number of the switch.

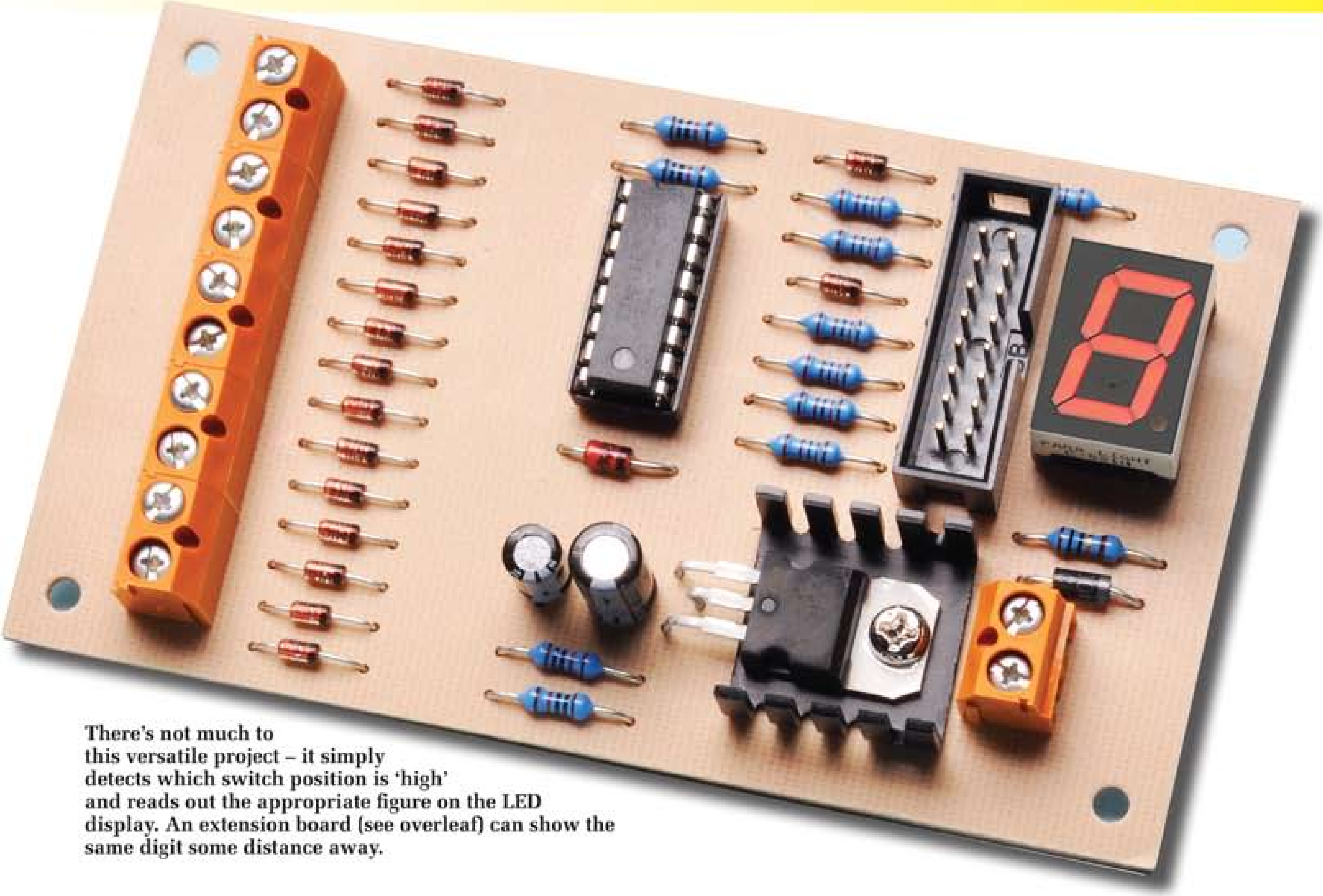
This brings us to another important point – the circuit is designed to operate correctly only if one switch is closed at the one time.

The arrangement of the reed switches and magnets should be such that as one switch opens, the next switch closes. In other words, there should not be a period when two reed switches are closed.

If two or more switches are closed, the display will show a blank or an incorrect value, which may be quite unrelated to the switches that are closed. For example, a closed 4 and 6 switch will show a 6, a closed 1 and 2 switch will show a 3, while a closed 8 and 3 switch will show a blanked display.

Circuit description

The circuit (Fig.1) for the Switch Indicator consists of the switch inputs,



There's not much to this versatile project – it simply detects which switch position is 'high' and reads out the appropriate figure on the LED display. An extension board (see overleaf) can show the same digit some distance away.

a diode matrix, a CMOS 4511 BCD to 7-segment decoder (IC1) and a single 7-segment common cathode LED display.

IC1 has four inputs, labelled A, B, C and D. These are normally held 'low' at 0V via the four 10kΩ pull-down resistors. When all four inputs are low, IC1 decodes this condition as zero, and it drives the 7-segment display accordingly, to show a 0. This is achieved by pulling its a, b, c, d, e and f outputs 'high' to drive the similarly labelled segments of the display via the 1.2kΩ resistors. For the 0 display, the central 'g' output remains low; its segment is not lit.

For those not familiar with BCD decoders and 7-segment displays, a look at Table 1 will be helpful.

The four columns on the left side of the table are labelled D, C, B and A, corresponding to the BCD inputs of the 4511 decoder. What we are talking about is a 4-bit BCD code; BCD stands for binary-coded decimal. So, if you look at the top row of the ABCD columns you will see that it shows 0000, and this corresponds to a numeric value of 0, as indicated at the top of the extreme right column.

The other columns in Table 1 show which of the seven segments of the display are illuminated. Hence, the top row of the table shows that all segments except 'g' are illuminated.

BCD INPUTS				SEGMENT OUTPUTS							DISPLAY
D	C	B	A	a	b	c	d	e	f	g	
0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	1	0	1	1	0	0	0	0	1
0	0	1	0	1	1	0	1	1	0	1	2
0	0	1	1	1	1	1	1	0	0	1	3
0	1	0	0	0	1	1	0	0	1	1	4
0	1	0	1	1	0	1	1	0	1	1	5
0	1	1	0	0	0	1	1	1	1	1	6
0	1	1	1	1	1	1	0	0	0	0	7
1	0	0	0	1	1	1	1	1	1	1	8
1	0	0	1	1	1	1	0	0	1	1	9

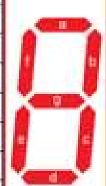


Table 1: here's how the 4511 chip decodes the switch inputs, in BCD (binary-coded-decimal and lights the appropriate segments in the LED readout (1s lit, 0s unlit). Any other BCD input results in all 0s, and therefore no segments lit. Note that the '6' shown here is the standard 4511 output – but we've modified it so that the 'a' segment lights as well (see right).

We reckon our 6 (left) looks a lot better than the standard 7-segment display 6 (right). All it costs is two diodes!

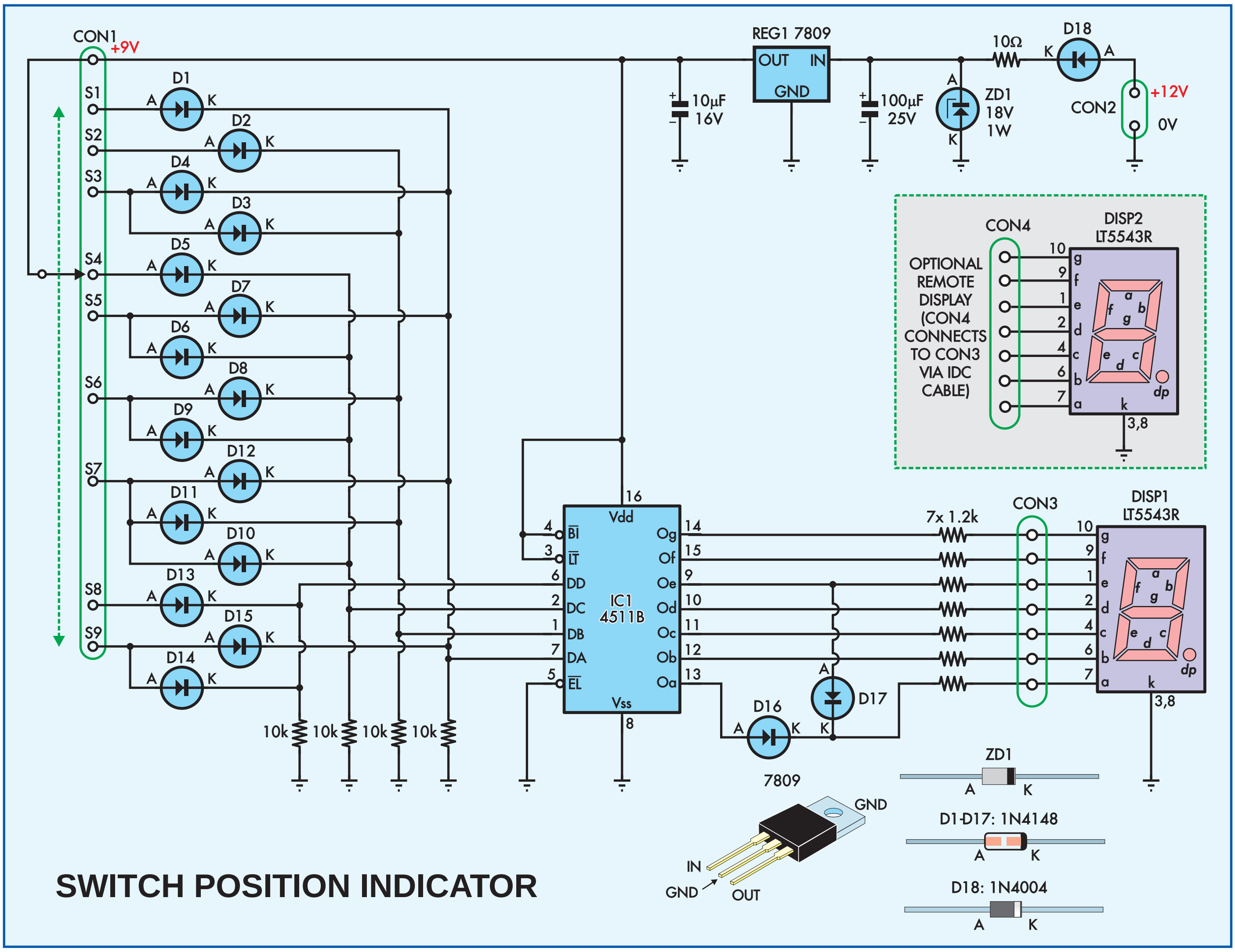


Fig.1: switch positions S1 to S9 are decoded by IC1, a BCD-to-7-segment decoder; the result displayed on the 7-segment LED readout. The optional remote display can be used some distance away.

Going back to the circuit diagram of Fig.1, if switch S1 is closed, the 9V supply is connected to the anode (A) of diode D1, and this pulls the A input of IC1 high. This is equivalent to a BCD value of 0001.

IC1 decodes this condition as a 1 and drives the b and c outputs high, while all other outputs are kept low. The b and c segments for the display now light to show the 1. This is shown in the second row of Table 1.

Similarly, if a different switch is pressed, then the diodes associated with that switch pull the respective A, B, C or D lines high to select the required digit to light. Table 1 shows the A, B, C and D input conditions to produce each number.

Special drive for 6

The display for the number six requires some explanation.

As shown in Table 1, the 4511 decoder creates a 6 by driving the c, d, e, f and g segments. This gives an abbreviated 6 (in our opinion), so we have modified the circuit to also include the top segment ('a') in the six display, using diode D17. This lights the 'a' segment whenever the 'e' segment is lit. Diode D16 is included to prevent the low 'a' output line from IC1 being driven high via diode D17.

This display modification does not affect any other numbers. This is because for other numbers, where the 'e' segment is lit (ie, the numbers 0, 2, and 8), the 'a' segment is already lit – and it doesn't get any brighter if more than one output drives it

Other inputs on the 4511 include pin 4, the Blanking Input (BI), pin 3, Lamp Test (LT) and pin 5, Enable Latch (EL). These functions are not used in our design, and so pins 3 and 4 are tied high while pin 5 is tied low.

Power for the circuit can come from just about any 12V DC supply (in fact, anything from 11V to 18V DC at 80mA or so will do). Diode D18 protects the input capacitor and regulator from reverse voltage connection, while the 10Ω resistor and 18V Zener diode gives transient protection. A 100µF capacitor filters the input to the 3-terminal regulator, REG1. This regulator provides a 9V output for the reed switch common connection and supply for IC1. A 10µF capacitor bypasses the regulator output.

Remote readouts

So far, we've only looked at a single LED display mounted on the main PC board. But we're sure (in fact, we know from experience) that there will be times when a remote display is also needed.

Therefore, we've designed the system to be very flexible. You can use the

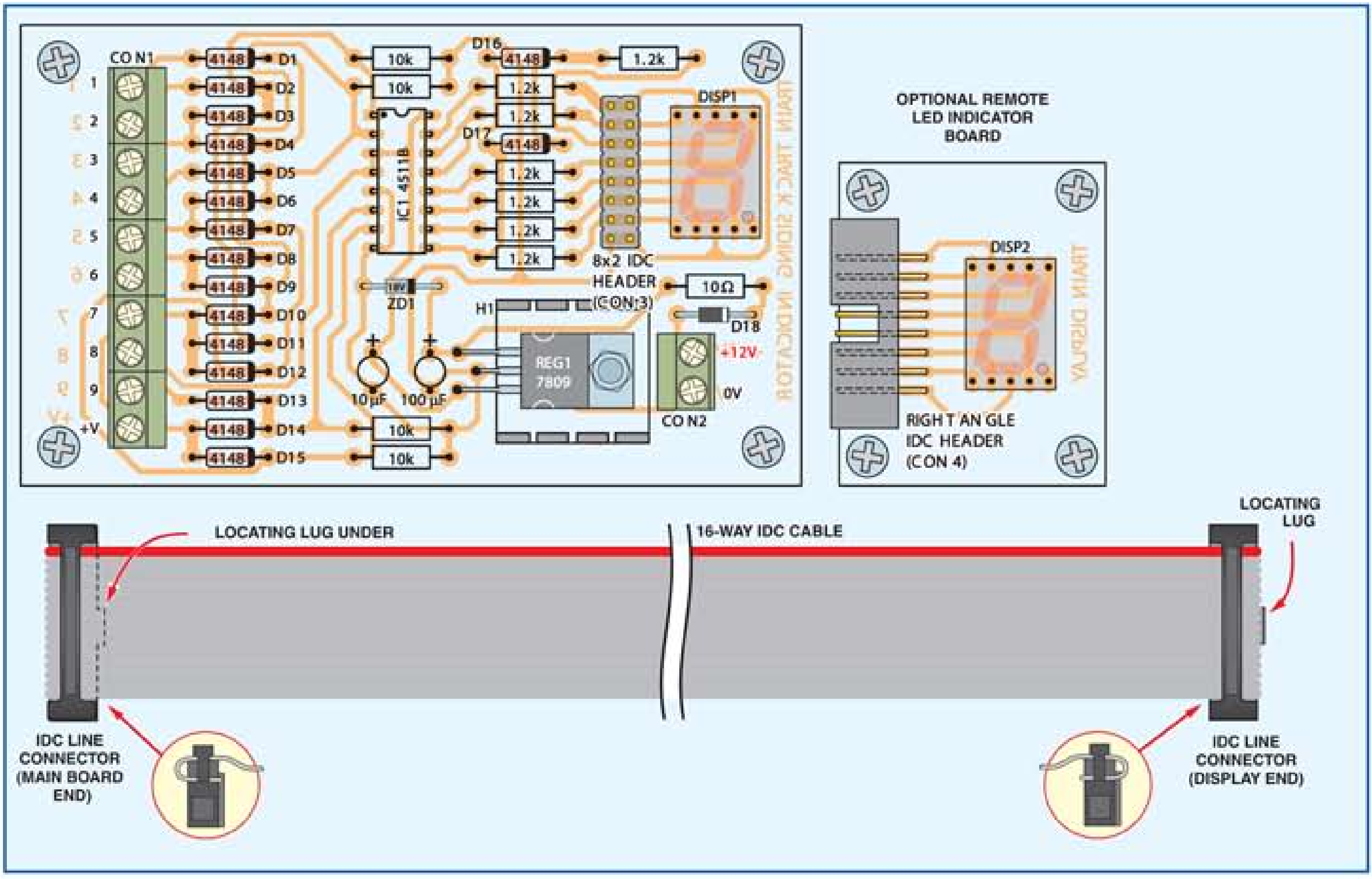


Fig.2 (top) shows the component layout for both the main PC board and the (optional) remote or extender board. The extender draws its power from the main board and is connected via the 16-way IDC cable, shown immediately above in Fig.3.

Parts List – Switch Position Indicator

+1 PC board code 827, size 104mm × 62mm
+1 Display PC board code 828, size 35mm × 43mm *
1 plastic UB3 box, size 130mm × 68mm × 44mm
1 TO-220 mini heatsink 19mm × 19mm × 9.5mm
6 PC mount 2-way screw terminals, with 5.08mm pin spacing
1 1m length 16-way IDC cable*
1 16-way PC mount IDC header*
1 16-way PC mount right-angle IDC header*
2 IDC line sockets*
1 20-way IC socket strip
1 DIP16 IC socket
1 M3 × 6mm screw
1 M3 nut

Items marked with an asterisk (*) are for optional remote display

Semiconductors
1 4511 BCD to 7-segment decoder (IC1)
1 LTS543R common cathode 7-segment LED display (DISP1) (or 2*)
1 7809 9V regulator (REG1)
1 1N4746 18V Zener diode (ZD1)
17 1N4148 switching diodes (D1 to D17)
1 1N4004 1A diode (D18)

Capacitors
1 100µF 25V PC electrolytic
1 10µF 16V PC electrolytic

+ Available from the *EPE PCB Service* as a pair

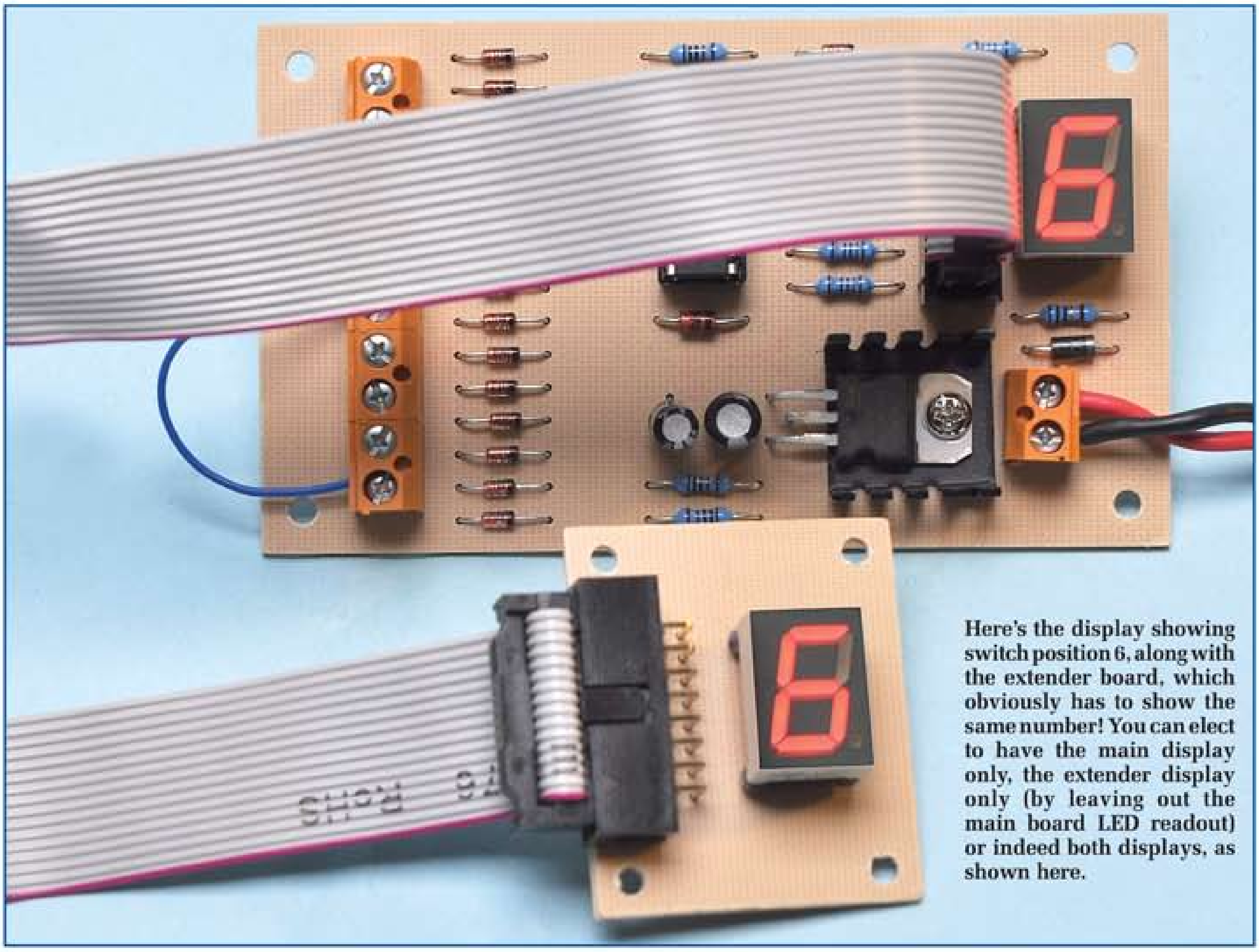
Resistors (0.25W 1%)
4 10kΩ (brown black orange brown or brown black black red brown)
7 1.2kΩ (brown red red brown or brown red black brown brown)
1 10Ω (brown black black brown or brown black black gold brown)

single display on the main PC board, or you can add a second, smaller, display-only PC board via a suitable length of IDC ribbon cable and have an extension readout (obviously this always displays the same digit as on the main board). Or you can even leave the display off the main PC board and simply have a single display a suitable distance away.

How far away? – because the LED segments only draw milliamps, there won't be much voltage drop over a ribbon cable, even several metres long. We're not stating a maximum distance – it's probably tens of metres or more – but if the remote display is noticeably dimmer than the main display, you've reached the limit.

Construction

The One-of-Nine Switch Position Indicator is constructed on a PC board



Here's the display showing switch position 6, along with the extender board, which obviously has to show the same number! You can elect to have the main display only, the extender display only (by leaving out the main board LED readout) or indeed both displays, as shown here.

(code 827) measuring just 104mm × 62mm. This board and the remote display board (code 828) are available as a pair from the *EPE PCB Service*.

The main board can clip into the integral mounting clips within a UB3-size plastic case if required. Alternatively, four corner mounting points are provided for mounting in a different box or mounted under a track layout. Fig.2 shows the component layout on the board.

The remote 7-segment LED display PC board (code 828) measures 35mm × 43mm. Its layout is also shown in Fig.2.

Main board

Begin construction by checking the PC board for breaks in copper tracks, or shorts between tracks and pads. Check that the hole sizes are correct for each component to fit neatly on the board.

The screw terminal holes are 1.25mm in diameter, and the 0.9mm holes are for the IC, resistors and diodes. REG1 should have a 3mm mounting hole for the metal tab, the corner mounting holes should also be 3mm in diameter.

The first components to insert on the board are the diodes and resistors. The diodes must be mounted with the orientation as shown. Diode D18 and Zener ZD1 have a larger body size compared to the other diodes (D1 to D17).

When inserting the resistors, use the resistor colour codes shown alongside the resistors in the parts list to check the resistor values (both 4-band and 5-band types are shown). A digital multimeter should also be used to measure each value as it is inserted.

REG1 mounts on a small heatsink, with its leads bent at right angles to insert into the PC board holes. Make sure the leads are bent at the correct length, so that the regulator tab can be secured to the PC board using a screw through the mounting hole in the PC board. Do this *before* soldering its leads.

The screw terminals can be mounted next, noting that the 10-way section is made from five 2-way sections locked together before they are inserted into the PC board.

IC1 can either be soldered directly into the board, or you can solder in a 16-pin DIP IC socket – either must be oriented with the notch as shown. Two 5-way socket strips are used for the 7-segment LED display.

If you intend using the separate display board, then you will need to mount a 16-way IDC PC-mount header for the interconnecting cable. This header has its notch closest to the display.

Install the two capacitors next, ensuring they are oriented correctly. If the display is to be mounted on the main PC board, then this can be inserted now. The decimal point is oriented to the lower right, as shown.

That completes the main PC board assembly, but if the remote display is required, the display PC board will also require assembly.

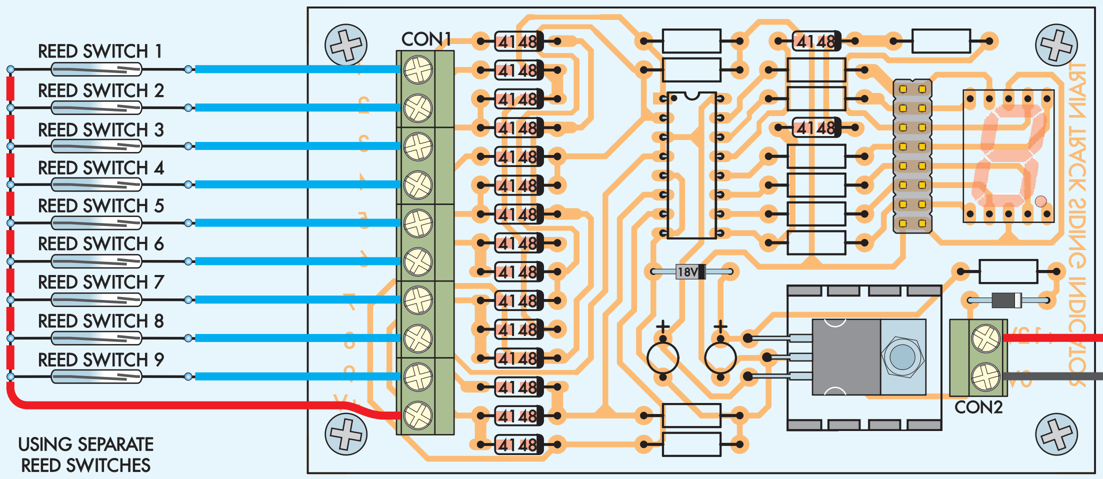


Fig.4 (left) shows how you would wire a set of reed switches, such as would be used on a model railway turntable or traveller with a magnet strategically placed on the moving section.

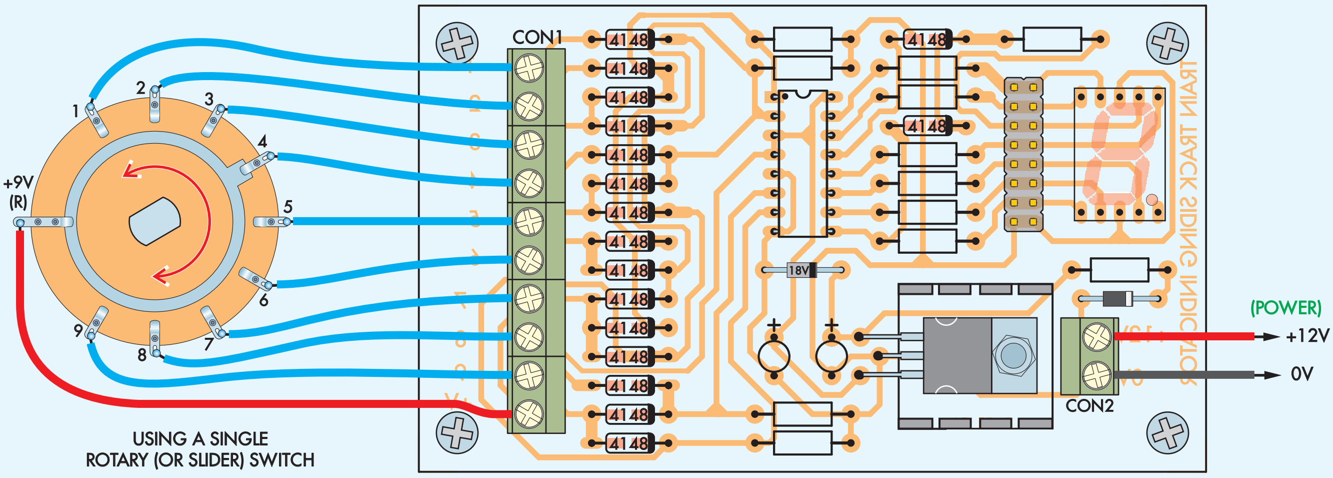


Fig.5: the wiring for a conventional 9-position switch. This could be part of a dual or multi-pole switch, as long as the poles remained isolated. This arrangement can be used for any number of applications requiring 'in use' identification.

Remote board

This PC board should also be checked for breaks in tracks or shorted tracks, and that hole sizes are correct. The right-angle mount 16-way IDC header mounts as shown, and the display can be mounted on two 5-way socket strips.

The 16-way IDC cable is made as shown in Fig.3, using a length of 16-way IDC cable and the two IDC sockets at each end. They are attached to the ribbon cable by clamping the socket halves around the cable in a vice.

Make sure the cable is oriented correctly, with the red stripe side located at the pin 1 edge of the IDC sockets. Pin 1 is indicated with a triangle shaped arrow embossed on the location lug side of the socket.

Testing

Apply power and check that the display shows a 0. If it does not, check that there is 9V between pin 16 and 8 of IC1. If there is no voltage here, check for approximately 9V at the output of REG1.

If the regulator does not deliver the right voltage it may be faulty (or the wrong type) or installed incorrectly (not easy to do). Diode D18 or Zener ZD1 may be faulty or installed back-to-front (much easier to do) or there may be a short circuit between the 9V and common ground on the PC board. Otherwise there is not much else that can be wrong.

When the display is working, a connection between the 9V terminal on CON1 and the 1 input should change the display to show a 1.

Similarly, a connection from the 9V to the 2 input should make the display show a 2, and so on.

A transparent red acrylic or perspex filter can be used over the display to improve the contrast (and therefore visibility) of the number.

In use

If the circuit is used with reed switches, Fig.4 shows how these are wired. One side of each switch is common and connects to the 9V terminal. The free end of each reed switch connects to the terminals on CON1. Not all nine reed switches need to be used – only the number of reed switches associated with the storage tracks need to be connected. Unused inputs are left disconnected.

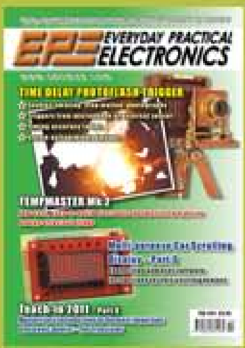
Fig.5 shows the equivalent connection for a single-pole rotary switch. We imagine that most applications requiring switch position indicators will in fact use a double-pole (or even multi-pole) switch. Just be certain to keep the original application and the Switch Indicator wiring isolated from each other!

Any other uses for the Switch Indicator should follow this basic approach. ***EPE***

EVERYDAY PRACTICAL ELECTRONICS

UK readers you can SAVE 79p on every issue of *EPE*

How would you like to pay £3.46 instead of £4.25 for your copy of *EPE*?



SAVE MONEY WITH A SUBSCRIPTION – buy now!

Well you can – just take out a one year subscription and save 79p an issue, or £9.50 over the year. You can even save £1 an issue if you subscribe for two years – a total saving of £24.00.

Overseas rates also represent exceptional value.

You also:

- **Avoid any cover price increase for the duration of your subscription**
- **Get your magazine delivered to your door each month**
- **Ensure your copy, even if the newsagents sell out**

Order by phone or fax with a credit card or by post with a cheque or postal order, or buy online from www.epemag.com (go to the 'UK Store').

EVERYDAY PRACTICAL ELECTRONICS

SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in the UK: 6 months £21.95, 12 months £41.50, two years £78.00; Overseas: 6 months £25.00 standard air service or £35.00 express airmail, 12 months £48.00 standard air service or £68.00 express airmail, 24 months £91.00 standard air service or £131.00 express airmail.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Tel: 01202 880299. Fax: 01202 843233. **Email:** subs@wimborne.co.uk. Also via the **Web** at: **www.epemag.com** (go to the 'UK Store').

Subscriptions start with the next available issue. We accept MasterCard, Maestro or Visa. (For past issues see the Back Issues page.)

ONLINE SUBSCRIPTIONS

Online subscriptions, for downloading the magazine via the Internet, $19.99US (approx. £13.00) for one year available from **www.epemag.com**.

SUBSCRIPTION ORDER FORM

☐ **6 Months: UK £21.95, Overseas £25.00 (standard air service), £35.00 (express airmail)**
☐ **1 Year: UK £41.50, Overseas £48.00 (standard air service) £68.00 (express airmail)**
☐ **2 Years: UK £78.00, Overseas £91.00 (standard air service) £131.00 (express airmail)**

To: Everyday Practical Electronics,
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU
Tel: 01202 880299 Fax: 01202 843233
E-mail: subs@epemag.wimborne.co.uk

I enclose payment of £ .... (cheque/PO in £ sterling only), payable to *Everyday Practical Electronics*

☐ Please charge my Visa/Mastercard/Maestro

My card number is: ....
Please print clearly, and check that you have the number correct

Signature ....

Card Security Code .... Valid From Date.......................
(The last 3 digits on or just under the signature strip)

Card Ex. Date ....Maestro Issue No. ....

Name ....

Address ....

Post code .... Tel. ....

Subscriptions can only start with the next available issue.

MasterCard Maestro VISA

Building the modules into a low-profile steel case

A high-quality stereo DAC for superb sound from your DVD player, Part 3

The final article this month shows you how to assemble the various modules for the Stereo DAC into a low-profile steel case. We also tell you how to get the remote control working and how to customise the configuration.

FOR THE purposes of this article, we'll generally assume that you're building the unit from a kit and that the case comes with all the holes pre-drilled. If not, then you will have to drill the holes yourself using the photographs and the layout shown in Fig.12 to guide you.

Basically, you will have to drill/cut holes in the front panel for the mains switch, the earth point (4mm), the three pushbutton switches (10mm) and the two LEDs (5mm). You will also need a 5mm hole for the IR receiver, plus four 3mm mounting holes for the Switch Board. **Note that the Switch Board is directly attached to the front panel and not mounted on a sub-panel, as in the prototype.**

Make sure that the cutout for the mains switch is the correct size, so that it snaps securely into place and is retained by its plastic locking tabs. This involves drilling a series of holes inside the marked cut-out, and then carefully (and tediously) filing it to shape. Alternatively, you can use a toggle switch that requires a round

By NICHOLAS VINEN

mounting hole, but make sure that the switch is mains rated.

On the rear panel, you will need clearance holes for the various input and output sockets, holes for the fuseholder and rear-panel earth point (4mm) and a cut-out for the IEC socket. An alternative here is to use an IEC socket with an integral fuse, in which case the external fuseholder is no longer necessary.

Drilling the bottom of the case is straightforward. First, use the PC boards as templates to mark out their mounting holes. **Note that the Input and DAC boards sit right at the rear of the chassis and their sockets must be correctly aligned with their rear panel holes to avoid shorts.** Drill these holes to 3mm, then drill two 4mm holes for the earth points, plus a mounting hole for the transformer. Having done that, fit four feet to the bottom of the case if it doesn't already have them. These can be either a self-adhesive type, or you can use bolt-on feet, in which case you will have to drill the necessary holes.

Mains wiring

Once the case is ready, the first step is to install the transformer, power switch and the 230V AC wiring. As shown in Fig.12, all the mains wiring is located in a partitioned-off area in the left-hand side of the case. However, this steel partition will only be present if you purchase a custom case as part of a kit. If you buy a standard rack case, then you can purchase a length of angle-aluminium from a hardware store and fit it yourself by bolting it to the base (make sure it is well *earthed* by scraping away any powder coating on the chassis around the mounting bolts).

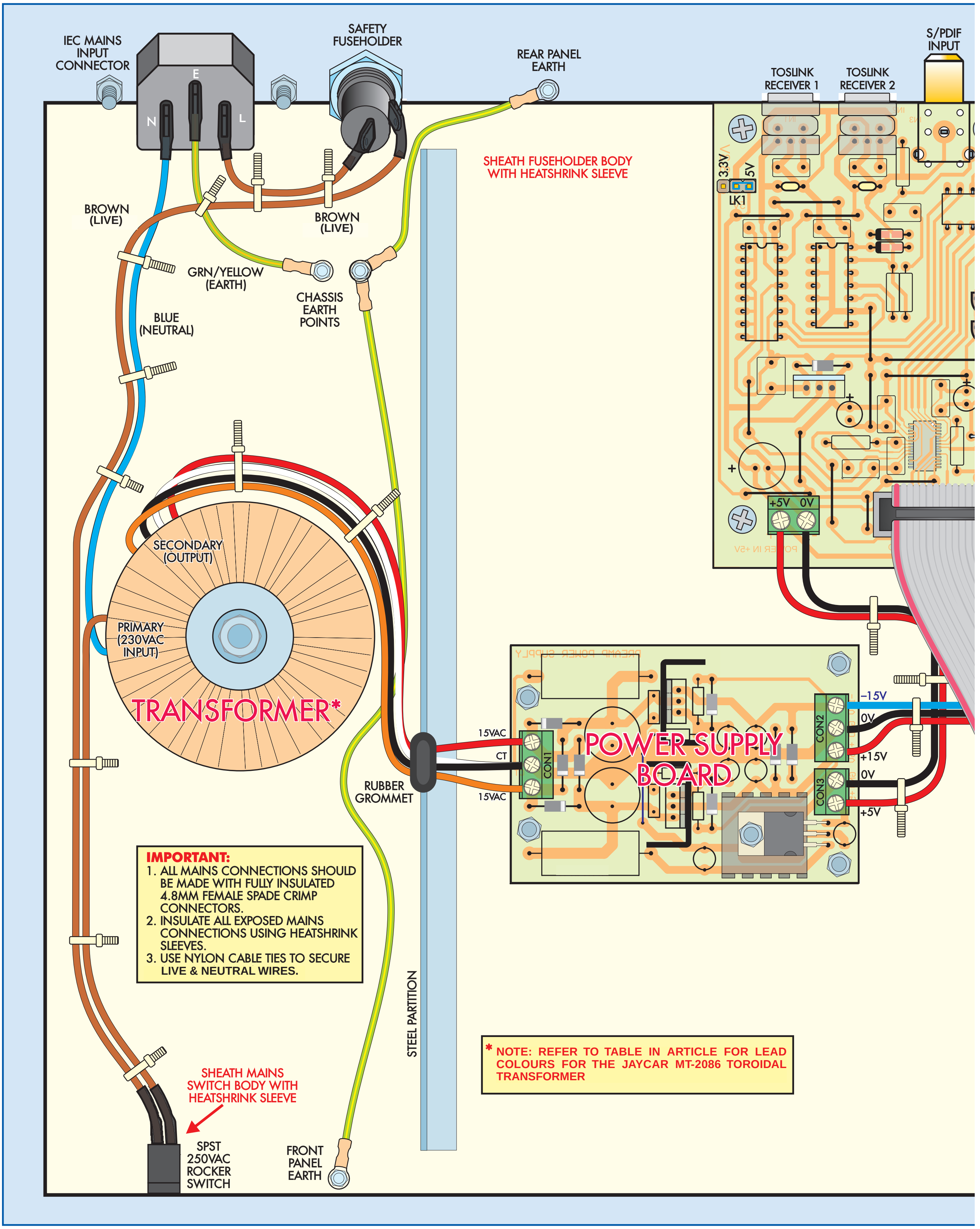
Before fitting the mains transformer, scrape away the powder coating around its mounting hole on the bottom of the chassis. This is done so that the flat metal washer under the head of the bolt contacts bare metal, thus ensuring the bolt is correctly earthed.

Having done this, mount the transformer in position. Note that the large flexible washer supplied with the unit must be installed between the transformer and chassis. A second flexible washer is then fitted between the top of the transformer and its dished metal clamp plate.

Orient the transformer so that the wires exit at the top, with the primary wires nearest to the side of the case – see Fig.12. Do not over-tighten the mounting bolt, otherwise you could distort the chassis.

The transformer's secondary side terminations can now be fed through a grommetted hole in the partition, ready for connection to the power supply board. Position all the wires so that there will be plenty of clearance to the lid when it is installed later.

NOTE: THE SUPPLY LEADS TO THE FINAL VERSION OF THE INPUT BOARD ARE REVERSED AT THE TERMINAL BLOCK COMPARED TO THOSE SHOWN HERE.



IMPORTANT:
1. ALL MAINS CONNECTIONS SHOULD BE MADE WITH FULLY INSULATED 4.8MM FEMALE SPADE CRIMP CONNECTORS.
2. INSULATE ALL EXPOSED MAINS CONNECTIONS USING HEATSHRINK SLEEVES.
3. USE NYLON CABLE TIES TO SECURE LIVE & NEUTRAL WIRES.

* NOTE: REFER TO TABLE IN ARTICLE FOR LEAD COLOURS FOR THE JAYCAR MT-2086 TOROIDAL TRANSFORMER

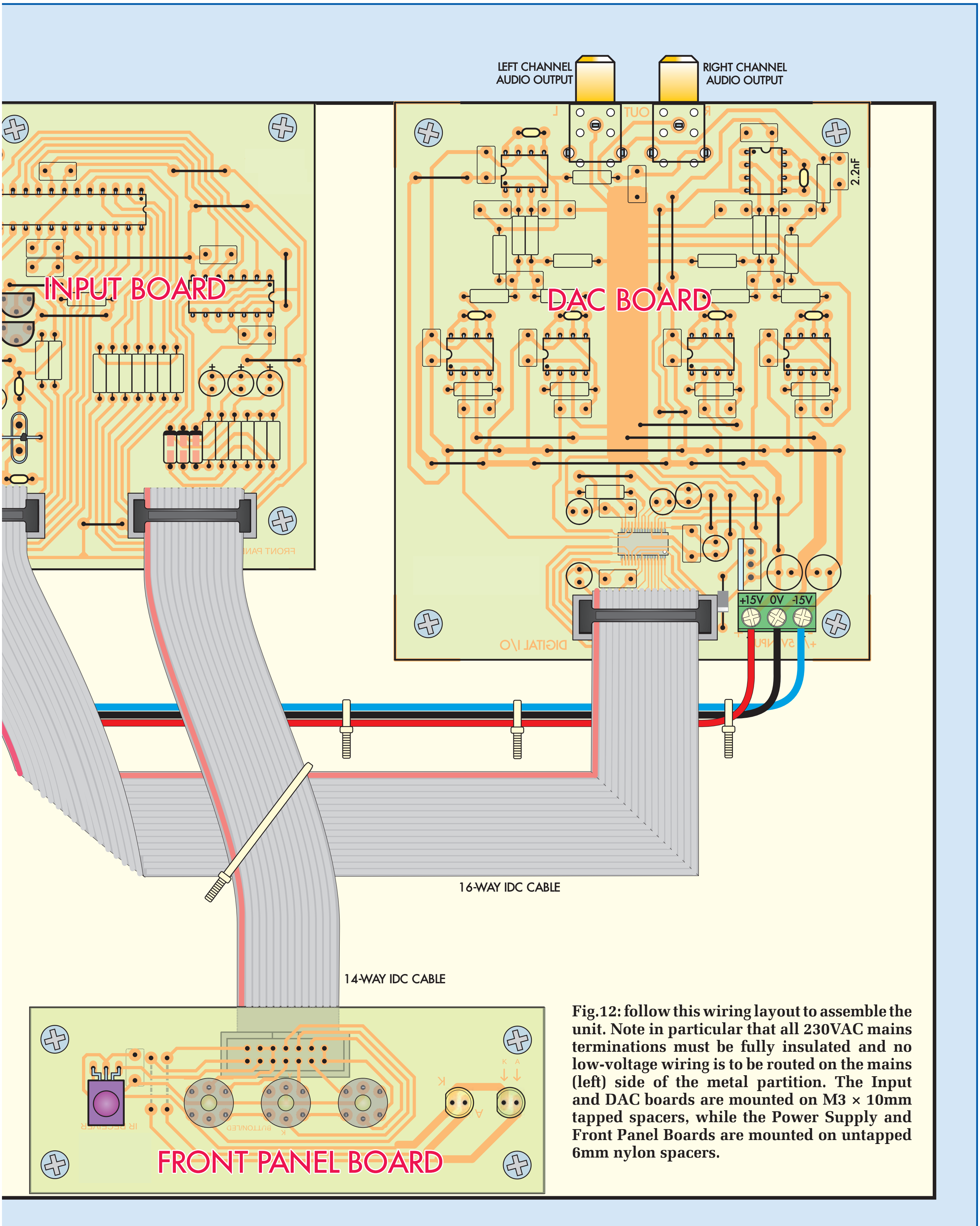


Fig.12: follow this wiring layout to assemble the unit. Note in particular that all 230VAC mains terminations must be fully insulated and no low-voltage wiring is to be routed on the mains (left) side of the metal partition. The Input and DAC boards are mounted on M3 × 10mm tapped spacers, while the Power Supply and Front Panel Boards are mounted on untapped 6mm nylon spacers.

The connections to the mains switch are made using fully-insulated spade connectors. Sheath the entire switch body with heatshrink sleeving after making the connections, and fit a cable tie to the wires immediately after the spade connectors so that they cannot possibly come loose. Note the earthing arrangement for the front panel.

A Jaycar toroidal transformer was used in the prototype, whereas the wiring diagram shows the lead colours for a different transformer – see Table 5 for the Jaycar version.

The Jaycar MT-2086 transformer uses orange leads for its primary, while its secondary leads are yellow, white, red and purple. In this case, the white and red leads go to the centre tap (CT) on the Power Supply Board, while the yellow and purple leads go to the outer 15V AC terminals.

Next, push the mains rocker switch and IEC socket into their respective cutouts, noting that the earth pin of the socket goes towards the top. That done, install the fuseholder. **Note that you must use a safety fuseholder as specified in the parts list in Part 1.**

You can now run and terminate the mains wiring. Use only 7.5A or 10A/250V AC mains-approved cable for all connections.

Do not solder the wires directly to the switch or socket pins! These devices are not designed to withstand high temperatures during soldering and may be damaged. Instead, terminate each wire end in a fully insulated 4.8mm female spade crimp terminal.

Note that a ratchet-driven crimping tool is required for this job. Low-cost automotive type crimpers are not suitable and their use may result in unsafe connections.

If you don't have fully-insulated spade connectors, be sure to fit heatshrink insulation over any exposed metal. **It's also a good idea to place a rubber boot over the IEC connector and to use 16mm-diameter heatshrink tubing to sheath the entire fuseholder (run the leads through the heatshrink first). Similarly, use 20mm-diameter heatshrink to sheath the power switch after attaching the leads.**

Table 5: Transformer lead colours

	Jaycar MT-2086
Primary Colours	Orange
Secondary Colours	Yellow
	White
	Red
	Purple

Player faults and detecting CDs with pre-emphasis

During testing, we came across at least one DVD player which incorrectly set the de-emphasis bit on its digital output when playing a CD. If your player has a similar fault, the effect of this would be that high frequencies are attenuated during playback.

As a result, the software in the Stereo DAC has been configured so that both the yellow and green LEDs are lit during playback when the de-emphasis is active. This can help you determine if your player has this same fault (unlikely), while for players that operate correctly, it will indicate if any of your CDs were recorded with pre-emphasis.

Pre-emphasis was mainly used on some older CDs and very few modern CDs use it. This means that if the yellow and green LEDs are always lit during playback, it indicates a fault with the player.

Down to earth

The connections to the chassis earth points are made by terminating the green/yellow earth leads in 5.3mm ID insulated crimp eyelets.

These eyelets are then bolted to the chassis earth points using M4 × 10mm machine screws, nuts and shakeproof washers. An additional nut is then fitted to serve as a locknut, so that the assembly cannot possibly come loose – see Fig.13.

Important: be sure to scrape away the paint from around the holes before fitting the earth screws (ie, you must have good metal-to-metal contact between the chassis and the earth eyelets). This step is vital to ensure safety.

Depending on the colour of the chassis, you might want to use black screws for the front and rear panel earth points. We used a black countersink hex head M4 × 12mm screw on the front panel to ensure good appearance.

Use small cable ties where applicable to keep everything neat and tidy. Refer to Fig.12 and the photos for all the details. In particular, fit cable ties close to the switch and to the IEC input socket, to make it impossible for any leads to accidentally come adrift.

Once the mains wiring is complete, go back over it and make sure that everything is correct. Check also that each connection is secure and well insulated. If necessary, use heatshrink tubing to completely cover any exposed terminations. That done, use your multimeter to check for continuity between the earth pin of the IEC socket and any convenient point on the chassis that is devoid of paint, such as the countersunk screws in the side panels.

This test must be repeated later when the top panel of the case is fitted. At that time, use your meter to check that the top and both side panels are earthed. If not, carefully remove the paint from beneath the heads of the retaining screws to ensure a reliable connection – see panel titled 'Making sure the case is securely earthed'.

Mounting the modules

The four PC board modules can now be installed in the case – see Fig.12.

Both the Input and DAC Boards are mounted on M3 × 10mm tapped spacers and secured using M3 × 6mm machine screws from either side. By

contrast, the Power Supply Board is mounted atop 6mm untapped nylon spacers and secured using M3 × 15mm screws, shakeproof washers and nuts.

Similarly, the Switch Board is secured to the rear of the front panel using 6mm untapped nylon spacers and M3 × 15mm screws, shakeproof washers and nuts. Make sure that the switches and LEDs just protrude through the front panel holes, and that the switches operate correctly, without jamming. The IR receiver LED must also be correctly aligned with its front panel hole.

Important: if the infrared receiver includes an external metal shield (see photo), then steps must be taken to ensure that it is insulated from the chassis. We suggest a short strip of ordinary insulation tape on the inside of the front panel, with a hole cut out to match the hole in the panel. Do not rely on the paintwork or powder coating to provide insulation!

Note that in the prototype (Jaycar rack case), the Front Panel Switch Board was fitted with spacers at the back and mounted on the sub-panel – see photos.

Low-voltage wiring

Now for the low-voltage wiring. First, trim the secondary leads of the transformer to the right length, then scrape the insulating enamel off the wire ends and tin them with solder. You should have about 5mm of tinned wire protruding from the insulation.

That done, solder the correct two secondary leads together to form the centre tap (CT). This will be the white and red leads for the Jaycar transformer. The secondary leads may then all be connected to the power supply module's AC input (CON1).

Before connecting anything to the output of the supply board, apply power (don't forget the mains fuse) and measure the three rails at the supply outputs (CON2 and CON3). Assuming all is well, the +15V, –15V and +5V rails should all be within ±5% of the nominal values. Now switch the power off and physically disconnect the 230V AC mains lead to prevent accidents while working under the 'hood'.

Input board

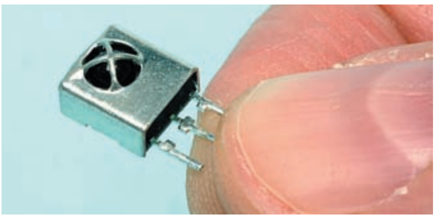
The +5V and 0V supply leads for the Input Board can now be run. Heavy-duty hook-up wire should be used for this job, and you should begin by stripping about 8mm of insulation from the ends of each wire.

That done, tin the bare ends with solder and trim them to about 5mm before connecting them to the terminal blocks on the Input and Power Supply Boards. It's a good idea to twist the two supply leads together to reduce noise and improve appearance, but be careful not to get them mixed up. Screw the terminals down tightly to ensure reliable connections.

Important: note that the supply leads to the Input Board used in the prototype are reversed at the terminal block compared to those for the final version of this board. The wiring diagram (Fig.12) is correct (ie, the positive lead goes to the left).

Note also that the ±15V supply leads to the DAC Board are not installed at this stage. That's done later, after you've tested the Input Board.

Secure the +5V and 0V supply leads with cable ties, as shown in Fig.12, so that they cannot come adrift and contact other parts of the circuit.



If your infrared receiver module has a metal shield like this one, then be sure to insulate it from the front panel, as described in the text.

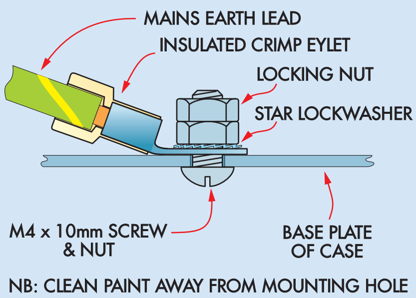


Fig.13: the earth terminals are all secured to the case as shown here. The top nut serves as a lock-nut, so that the assembly cannot possibly come loose. Make sure that the crimp eyelet makes a good electrical contact with the base.

Testing the Input Board

You are now ready to do some initial tests, starting with the Input Board.

Begin by plugging in the 14-way IDC cable between this board and the Front Panel Switch Board, then connect a multimeter in series with the +5V supply. You will have to temporarily disconnect the +5V supply lead at one end (eg, at the Power Supply Module) to do this.

Set the multimeter to the amps range, then apply power and check the current reading. It should be around 0.1A and certainly not more than 0.2A. If you see a reading of 0.2A or higher, switch off immediately, disconnect the power cord and check the Input Board for short circuits and incorrect parts placement.

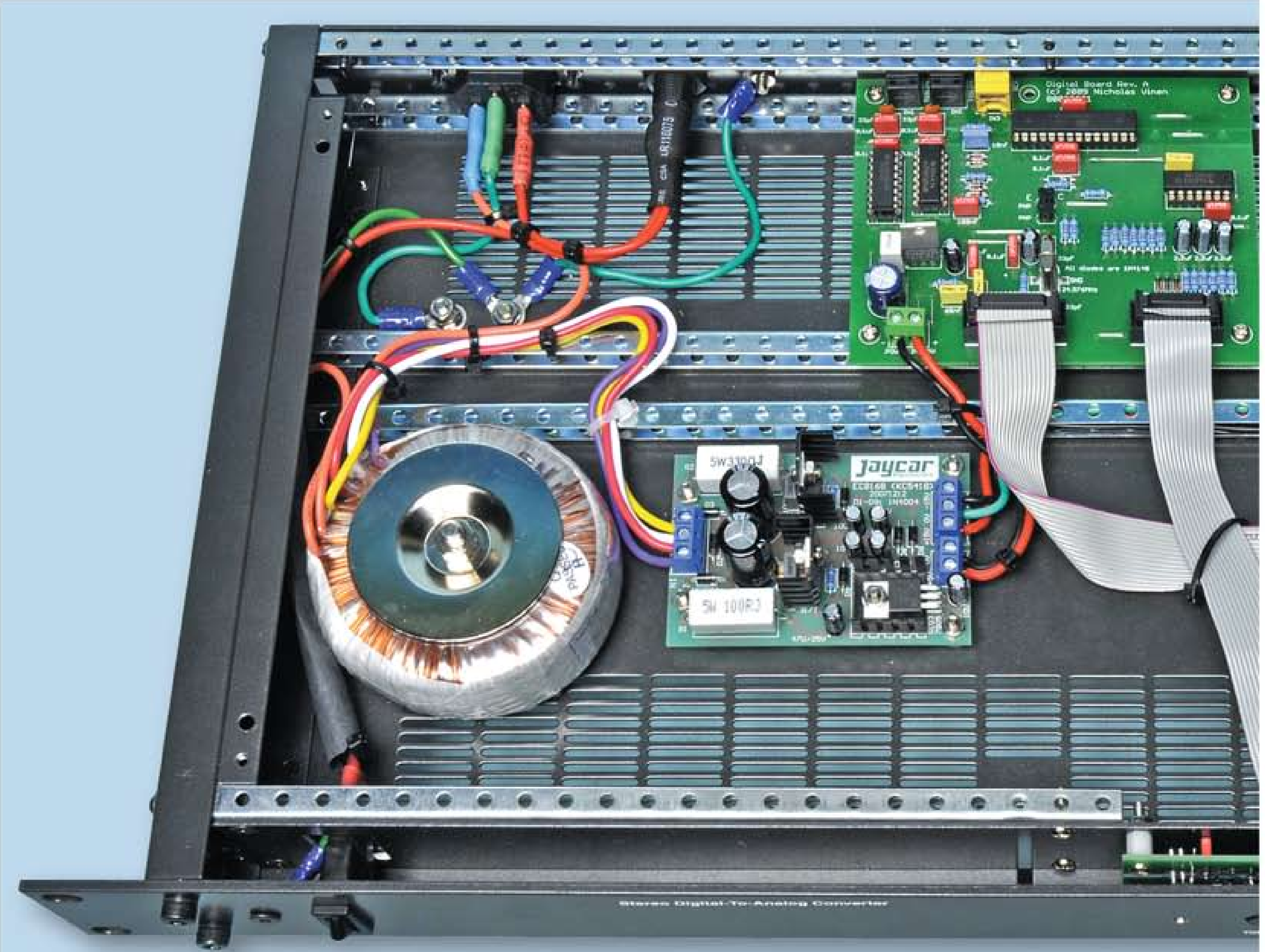
If that doesn't solve the problem, disconnect the 14-way IDC cable and quickly re-apply power in order to rule out a fault with the cable or Front Panel Switch Board.

If the current is in the acceptable range, check that the blue LED on the front panel nearest the IR receiver is lit. No other LEDs should be lit initially, but after about 10 seconds, the unit should enter scanning mode, whereby each LED briefly lights in sequence. If that checks out, switch off, remove the multimeter and reconnect the +5V lead to the terminal block.

The next step is to feed a signal into one of the inputs (ideally you should test all three inputs). If your DVD player (or CD player) has a TOSLINK output, connect it to the TOSLINK1 input on the Stereo DAC using an optical cable. The player needs to be switched on for this initial test, but not playing anything.

Now power the unit back up. The TOSLINK1 blue LED should be lit, along with the S/PDIF yellow LED. If either LED fails to light, switch off immediately and check for faults on the Input and Front Panel Switch Boards. One of the most common causes of LEDs not lighting up is cable crimping problems, so check this out carefully. Other possible faults include shorts between adjacent pads, missing links, missed solder joints and incorrect parts placement or orientation.

Assuming all is well, you are now ready to test the other two inputs. Press each button in turn and make sure that its corresponding blue LED lights. The yellow LED will go out if there's no



The prototype was built into a Jaycar 1U rack case. If you do use the Jaycar case, fit covers over the ventilation slots above and below the mains wiring.

What to do if there's no audio output from the stereo DAC

In order for the Stereo DAC to work correctly, it must be fed with LPCM (linear pulse code modulation) data from the DVD player (ie, uncompressed audio). If there's no audio output and the green and yellow LEDs on the Stereo DAC front panel are flickering rapidly, this indicates that the output from the DVD player is set to AC3/Dolby Digital. In that case, you will have to step through the menus of the DVD player and set the audio output to stereo LPCM.

Note that on one recent Pioneer DVD player we tested, it was impossible to change the audio output format with an HDMI cable hooked up. The trick was to disconnect the HDMI output and use either component video or a composite video connection instead. This then allowed the AC3/Dolby Digital output to be changed to stereo LPCM, after which the HDMI connection could be re-instated. Other DVD players may require a similar procedure.

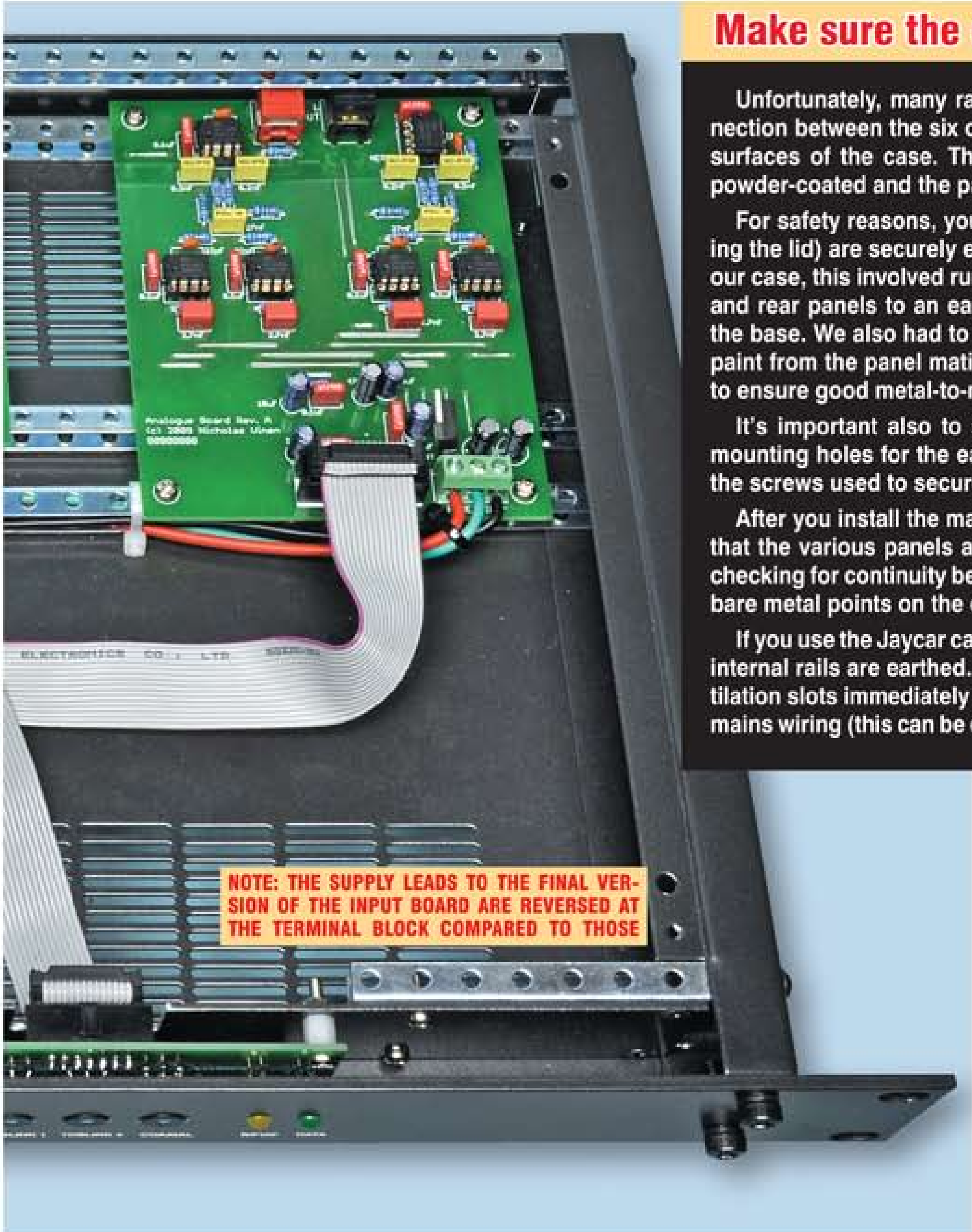
signal input for that channel. If that checks out, connect the DVD player to the TOSLINK 2 and COAXIAL inputs in turn and check that the yellow S/PDIF LED lights when the corresponding input is selected.

Note that these tests (and the following tests with the remote control) are all done without the ±15V supply wiring in place.

Testing the remote control

This unit can be controlled using a Philips RC5-compatible remote control. That includes just about any universal remote.

You will need to program the remote to control a Philips TV. For example,



NOTE: THE SUPPLY LEADS TO THE FINAL VERSION OF THE INPUT BOARD ARE REVERSED AT THE TERMINAL BLOCK COMPARED TO THOSE

Make sure the case is securely earthed

Unfortunately, many rack mount cases have no electrical connection between the six or more panels that make up the external surfaces of the case. That's because they are either painted or powder-coated and the paint/powder coating acts as an insulator.

For safety reasons, you must make sure that all panels (including the lid) are securely earthed when the case goes together. For our case, this involved running separate earth leads from the front and rear panels to an earth point adjacent to the mains earth on the base. We also had to dismantle the case and scrape away the paint from the panel mating surfaces and under the screw heads, to ensure good metal-to-metal contact when it all goes together.

It's important also to scrape away the paint from around the mounting holes for the earth screws, the transformer bolt and for the screws used to secure the rubber mounting feet.

After you install the mains wiring, use your multimeter to check that the various panels are correctly earthed. You can do that by checking for continuity between the earth pin of the IEC socket and bare metal points on the chassis panels.

If you use the Jaycar case, then you must also make sure that the internal rails are earthed. We also suggest that you cover the ventilation slots immediately above and below the IEC socket and any mains wiring (this can be done using black plastic or metal panels).

if you have a Jaycar AR-1726 remote, you need to set its code to 103 with the TV control mode selected.

Having done that, point the remote at the Stereo DAC's front panel and press some buttons. The yellow LED should flash each time a button is pressed. If so, you should then be able to select each input in turn using the 1, 2 and 3 buttons on the remote or by pressing the CH+ and CH– buttons.

If you don't wish to use the Philips TV code (eg, if you have a Philips TV), you can set the unit up to recognise a different RC5 code (see Programming The Remote Control Codes).

Note, however, that not all Philips remote control codes use the RC5 protocol. If you set a universal remote control to a Philips code, but the DAC doesn't recognise it, try using a different code. You may have to go through several before you find a code that works.

Final testing

You are now ready to test the complete unit. To do this, first switch off, disconnect the DVD player and disconnect the mains lead. Now install the +15V, 0V and –15V leads between the Power Supply Board and the DAC Board. As before, use heavy-duty hook-up wire and twist the wires together to minimise noise pick-up. Secure the leads using cable ties, as shown, and tighten the terminal block screws down firmly to ensure good connections.

Finally, check that these supply leads are correctly wired at both ends.

The next step is to fit the 16-way IDC cable. **Note: do not apply power to the DAC board unless it is connected to the Input Board via the 16-way cable.**

Once everything is in place, apply power and check the ±15V supply rails at the input to the DAC board. If these are OK, check the +5V rail at the output of REG5 on the DAC Board. Switch off immediately and check for errors if any of these voltages are incorrect.

If all is well, the front panel LEDs should light as before. It's now just a matter of checking that the unit works.

Connect your DVD player to the TOSLINK1 input (or to the COAXIAL input if there's no TOSLINK output on the player) and check that the yellow S/PDIF LED lights when that input is selected. In fact, the unit should automatically select that input if it was scanning. Now start playing a CD or DVD – the S/PDIF LED should immediately turn off and the green DATA LED should come on.

If that doesn't happen, there may be a problem with the DAC (IC6), the 16-way cable or one of the parts asso-

Programming the remote control codes and customising the configuration

It isn't necessary to configure the Stereo Digital-To-Analogue Converter before use. Most constructors will be happy to settle for the default settings in the firmware, but some people may wish to customise it to suit their individual needs. Basically, you can change the remote control codes, the scanning behaviour and the initial input selection (TOSLINK1 is the default) when the Stereo DAC is switched on.

Virtually any universal IR remote control can be used, including the Digitech unit from Jaycar (Cat. AR-1726). Set the Digitech unit to code 103.

If you are using a universal remote, the simplest solution is to set it to control a Philips TV. This will allow the CH+ and CH– buttons to select the inputs. And if your remote has numeric buttons, you can also use buttons 1, 2 and 3 to select a particular input.

In addition, the Mute button should toggle mute on and off. While muted, all three blue LEDs should flash in unison to indicate this condition. Finally, the VOL+ and VOL– buttons should control the Stereo DAC's volume. Check that these functions all work.

Remote control reprogramming

The yellow LED should flash whenever a button on the remote is pressed. If you can get it to flash, but not all the functions work or if you don't want to use the Philips TV codes (eg, if you have a Philips TV), then you can reprogram the unit to accept different codes.

To do this, hold down all three buttons on the front panel at once, then release them. Be sure not to release any until all three have been pressed or you may get into the wrong mode (if you do, just turn the unit off and then on again).

When the buttons are released, the left-hand blue LED will be flashing. Point your remote control at the IR receiver and press the button that you want to assign to select TOSLINK1. Hold it down for a few seconds until you see both the yellow and green LEDs flash. The first blue LED should then stop flashing and the second should start, at which point you should release the button on the remote.

If the yellow and green LEDs don't flash, make sure that the remote control is transmitting an RC5 code. Provided that you choose a Philips code, you will be OK, but that might not apply to the codes for other manufacturers. Check also that the remote's batteries are OK.

If the first blue LED is still flashing, stop for a few seconds and try again. The Stereo DAC waits until it receives 10 identical codes in a row before programming that code. This is done to avoid the possibility of a transmission error programming in the wrong code.

If you don't want to assign that function to a button on your remote control, press any of the front panel buttons on the Stereo DAC to skip it.

You now repeat the above procedure for the following functions in this order: Select TOSLINK2, Select COAXIAL, Select Next Input, Select Previous Input, Mute Output, Volume Up and Volume Down. Each time you program a code, the flashing blue LED should cycle to the next button, wrapping around from the third to the first.

Once all the codes have been programmed, the LEDs will stop flashing and the Stereo DAC will revert to its normal mode. You can then check that

ciated with the DAC chip. You should also check the two BC327 *PNP* transistors on the Input Board and their associated resistors.

Assuming that it all works so far, switch off and connect the Stereo DAC's outputs to an amplifier, turn the volume down and reapply power. Now play some content and slowly turn the volume on the amplifier up. You should hear clean, undistorted sound.

Once you have verified that this works, test the other two inputs. Check also that you can adjust the volume from the Stereo DAC up and down using the VOL+ and VOL– buttons on the remote control. However, as explained in Part 1, it's best to set the volume from the Stereo DAC to maximum if you want the best performance and use the volume control on the amplifier instead.

Table 6: Selecting The Programming Function

Function	First Button	Second Button
Auto-Scan Delay, No Signal Present	1	2
Auto-Scan Delay, No Audio Present	1	3
Auto-Scan Delay, No Signal Present After Manual Input Change	2	1
Auto-Scan Delay, No Audio Present After Manual Input Change	2	3
Default Input At Switch-On	3	1
Input Scanning At Switch-On	3	2

Table 7: Setting The Multiplier

Value	Button
10ms	1
Seconds	2
Minutes	3

Table 8: Setting The Delay Value

Value	First Button	Second Button
1	1	1
2	1	2
3	1	3
5	2	1
10	2	2
20	2	3
30	3	1
40	3	2
50	3	3

the remote control codes have been properly assigned. If not, start again.

Scanning delays/default input

The scanning delays and the initial default input can also be reprogrammed. This is done by holding down one button on the front panel, then pressing a second button and releasing both together.

The buttons pressed and their order determines which function you are configuring, as set out in Table 6.

After pressing one of these combinations, the left-hand blue LED will flash. Each additional button press after that will cause the flashing LED to cycle to the next step until the configuration is complete.

To set any of the auto-scan delays after selecting the configuration mode, you first press one of the buttons to get a multiplier value – Table 7. It's then simply a matter of making two further button presses to set the delay value, as shown in Table 8.

As an example, if you wanted to set the delay to five minutes, you'd press and release button 3 (Table 7), then button 2 and finally button 1 (Table 8). The default auto-scan delay values are (in the order shown in Table 6) 10 seconds, one minute, five minutes and never.

By the way, the sequence 1, 1, 1 is a special sequence, which is interpreted as 'never' and thus disables that scanning mode.

Default input

There are two choices when it comes to programming the default input: (1) you can either have the unit remember the last channel it was set to and restore that channel at switch on, or (2) you can program the unit to always select one of the inputs.

If you want it to remember the last channel, select the 'Default Input At Switch-On' function by pressing the buttons shown in Table 6, then press button 1. Alternatively, to always select a certain input, select the function, then press button 2 and then the button for the input that you want selected.

The default state is for TOSLINK1 (Input 1) to be selected at switch on, and most readers will probably leave it at that. However, you might want to change it to Input 3 (COAXIAL) if you are only using the COAXIAL input.

Scanning behaviour

There are three options for input scanning behaviour on start up:

1) To configure the unit to immediately begin auto-scanning, select the 'Input Scanning At Switch-On' function from Table 6 and press button 1 (left)
2) To configure it to begin scanning after the usual auto-scanning delay (the default behaviour), press button 2 (centre)
3) To make it act as if the default channel has been manually selected at switch on, press button 3 (right).

Wait – there's more!

There's one other feature we haven't mentioned. Even if you have auto-scanning enabled, there may be times when you don't want it to happen.

In that case, all you need to do is switch to the input that you want to lock and then press the selector button a second time, holding it in for about a second. The LED will come on, but blink off occasionally to indicate this 'input lock' mode has been enabled.

In this mode, auto-scanning is disabled. However, the next time you manually change the input, or when you turn the Stereo DAC off, it will reset to the default mode.

Enjoy the sound

That's it – your new Stereo Digital-To-Analogue Converter is now ready for use. Hook it up permanently to your system and you can now enjoy high-quality, hum-free stereo sound from your DVD player. *EPE*

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

IN RECENT years, the semiconductor manufacturers have rationalised their ranges and the number of devices on offer has probably reduced somewhat. This is not readily apparent when looking through component catalogues, where the number of different devices listed is likely to be at least a few hundred. In the case of a major professional supplier there will be many thousands of semiconductors available.

It is an area of electronics where it is necessary for even the most experienced of electronics enthusiasts to proceed with caution, because it is easy to make a mistake when there are so many components of a single type listed, many of which have similar type numbers. Buying the wrong device, or the right device but the wrong version of it, is something that can easily happen if you do not take due care.

Type number anatomy

Mistakes are less likely to occur if you understand the basic anatomy of a semiconductor part number. No doubt there are exceptions, but they are mostly in three sections. There is usually a prefix that provides some basic information about the device, but the methods of coding used are very basic and never tell you much about a particular device.

However, when buying components the prefix can be, and often is, very important. The middle section is the main part number and is usual a serial number having three or four digits.

The suffix provides some additional information about the device, but it is not always present, particularly with transistors and diodes. It is only necessary when there are two or more different versions of a device, and the suffix is then needed to distinguish one version from another.

Again, this is important when buying components, and you could easily end up with the wrong version if you obtain a device that does not have the correct suffix. Matters are not entirely straightforward with semiconductor suffixes though, and there are many instances of identical devices that have different suffixes.

Middle management

The basic type number is the most straightforward part of a semiconductor type number. The first device of that type to be registered could have the number '0001', the next one would then be '0002', and so on. Things do not always work quite like this, and with some transistors for example, there are three digits and the numbering seems to start at '100' rather than '001'. The method used is not of any great practical importance though.

There is a slight flaw in the use of three and four-digit type numbers, which is simply that there are more semiconductors than available type numbers. A device having a '555' type number could be the popular timer integrated circuit (IC), a transistor having a European type number, and possibly something else, such as another type of integrated circuit or an optical device.

The basic type number is important, but is not in itself enough to ensure that the right part is obtained. You have to be careful to buy the right type of component (transistor, diode, or whatever), and the other parts of the type number have to be taken into consideration.

In the beginning

The initial part of the type number generally has one of two functions, and with devices having European Pro Electron type numbers it usually gives some basic information about the type of device. This coding has its origins back in the days of thermionic valves, but in a modern context the first letter indicates the type of semiconductor material used or the type of integrated circuit, as in Table 1. The second letter indicates the type of device, as in Table 2. Some of the more specialised types have been omitted from these tables. Also, devices intended for industrial applications have a third letter, but

Table 1

First letter	*Semiconductor type*
A	Germanium
B	Silicon
C	Band gap (gallium arsenide)
F	Logic integrated circuit (TTL, DTL, etc.)
R	Photocell (non-semiconductor)
S	Digital integrated circuit
T	Linear integrated circuit

Table 2

Second letter	*Type of device*
A	Signal diode
B	Variable capacitance diode
C	Low power audio transistor
D	High power audio transistor
E	Tunnel diode
F	Low power radio frequency transistor
L	High power radio frequency transistor
P	Phototransistor
S	Switching transistor
T	Thyristor or triac
Y	Rectifier
Z	Zener diode

only a two-digit type number instead of a three digit type.

As a couple of examples, a BC550 is a small silicon transistor for audio or other low frequency applications; while a BF181 is a low-power silicon transistor for use at radio frequencies.

One short

Simple semiconductors that have American JEDEC (Joint Electron Devices Engineering Council) type numbers have a prefix that consists of a number followed by the letter 'N'. The number is one less than the number of leadout wires that the device possesses, which in practice means it is '1' for diodes and rectifiers, '2' for normal transistors, and '3' or more for special devices, such as dual-gate MOSFETs.

A 1N4148 is therefore a device that has two leadout wires, which usually means a rectifier or diode. It is actually a small diode, but this information is not conveyed by JEDEC type numbers, which are less helpful than the Pro Electron ones.

Japanese JIS (Japanese Industrial Standards) type numbers are not often encountered these days, but the first digit is again a number that is one less than the component's number of leadout wires. This is followed by two letters that identify the general type of device, and some of the more common ones are provided in Table 3. For normal types of transistor the first two digits are always '2S', and perhaps a little unhelpfully, these two digits are sometimes omitted from the type number.

Table 3

Code	*Device type*
SA	High frequency *PNP* transistor
SB	High frequency *NPN* transistor
SC	Audio *PNP* transistor
SD	Audio *NPN* transistor
SE	Diode
SJ	P-channel FET or MOSFET
SK	N-channel FET or MOSFET
SR	Rectifier

Manufacturer

Most of the simple types of semiconductor have type numbers that conform to one of the standard methods, but there are some exceptions (Fig.1). It is different with integrated circuits (ICs), where relatively few devices have type numbers that conform to any national or international type numbering system. The first two or three digits of the type number are letters that identify the manufacturer (Fig.2).

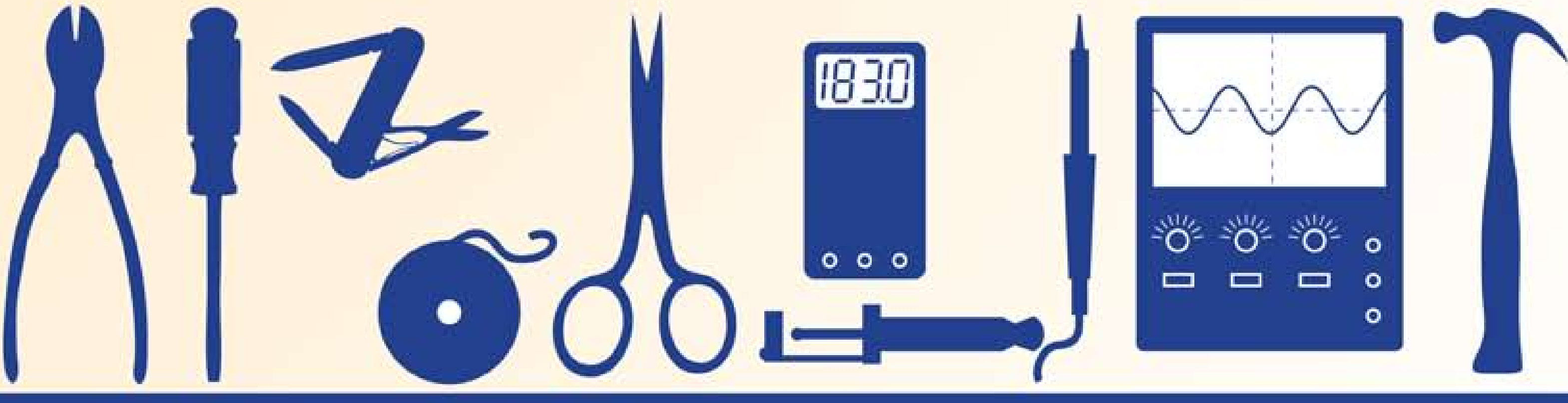
As a couple of examples, the prefixes 'CA' and 'MC' are used respectively by RCA and Motorola. There is a slight complication here, which is that some devices are produced by more than one manufacturer. This usually results in each manufacturer using their own prefix code rather than the one used by the originator of the device.

There are definite advantages to having components produced by more than one manufacturer, or 'second sourcing' as it is usually termed. One or more alternative sources introduces competition that helps to keep prices down, and is less of a problem if the originator of the device decides to 'pull the plug' on production. On the other hand, having the same component available under slightly different type numbers can make it difficult to find the right component when looking through a list of devices that uses some form of alpha-numeric sorting, or when using an online search facility.

When looking through a catalogue for an integrated circuit, it is probably best to ignore the prefix and concentrate on the other two sections. Component retailers do not necessarily guarantee to supply devices from specific manufacturers. If you order (say) an MC1458CP, but are supplied with a CA1458E, or *vice versa*, there is no need to worry. They are both 1458 dual operational amplifiers (op amps), and there is no practical difference between the two. The MC1458CP is made by Motorola or Texas Instruments, while the CA1458E is produced by RCA. There is insufficient space available here for a comprehensive list of manufactures' prefixes, but a huge list is available on the Wikibooks website: **http://en.wikibooks.org/wiki/Practical_Electronics/Manufacturers_Prefix**

Fig.1. The 'TIP' prefix of this power transistor indicates it is a so-called 'plastic power' transistor from Texas Instruments. However, it is marked as being manufactured by MOSPEC, so it is a second source device

Fig.2. This integrated circuit (IC) has 'LM' as the prefix of its type number, indicating that it was made by National Semiconductor. It could well be another second source device as it lacks any markings to suggest it was made by the originators of the chip



Endless

Most transistors do not have a suffix to the type number. Where it is present, it is usually in the form of a single letter that indicates the gain group of the device. This normally works on the basis of a letter 'A' for low gain devices, a 'C' for those having the highest current gains, and a 'B' for those of middling performance. A components list will sometimes specify a particular gain group, and it is then important to obtain the correct type. It is otherwise safe to simply ignore any gain group suffixes.

There are a few transistors that have a suffix letter that indicates the leadout configuration used for the device. The suffix letter is usually an 'L' or a 'K'. Fortunately, this method never became popular, and most transistors that are available with more than one leadout configuration or encapsulation have a different serial number for each type.

The situation is very different with integrated circuits, where it seems to be the norm for devices to be available in a variety of case styles. These days, this usually means a device that has a standard DIL (dual in-line) encapsulation of some sort, plus various surface-mount options.

Clearly, the suffix of an integrated circuit is something that cannot be ignored. Obtaining a device that has the wrong suffix is likely to result in the right semiconductor chip being obtained, but in an encapsulation that is physically incompatible with the project you are building.

Matters are complicated by a lack of standardisation for integrated circuit suffixes. In the 1458 example given earlier, the two type numbers have different suffixes ('CP' and 'E'). In the first example, the C indicates that it is a standard DIL device, and the P shows that it is in a plastic casing. The E in the second example means that it is a DIL device in a plastic package, in other words, exactly the same component as the 'CP' version.

In other words, by obtaining an IC that has the wrong suffix you could be obtaining a component that is totally incompatible with the circuit board you are using, or it might be the right device with an alternative suffix from a different manufacturer. The information in the catalogue should help you to avoid mistakes. Semiconductors are usually listed in groups rather than one huge list. There are different sections for transistors, rectifiers, linear integrated circuits, and so on. Catalogues usually indicate the type of case and pinout configuration for each device listed, and this is perhaps a more reliable guide than the suffix, particularly with chips that are produced by several manufacturers.

Quick decisions

Some integrated circuits have a suffix that indicates the speed of the device. This system is mainly used with memory and certain other computer chips, such as microcontrollers and microprocessors. In most cases, the extra digits are really an extension of the basic type number rather than a suffix, since the extended type number will usually be followed by a conventional suffix that denotes the case style of the component. Some PIC microcontrollers for example, have something like '-20' added to the basic type number. The additional figure indicates the maximum clock frequency (in megahertz) for the chip.

In general, it is safe to use a component having a better speed rating than the one called for in a components list. However, faster versions tend to be significantly more expensive than the slower ones. Using a chip with an inadequate speed rating more or less guarantees that the project will not work at all.

Now you see it...

Not all integrated circuit type numbers adhere strictly to the standard arrangement of a basic type number plus a prefix and an optional suffix. The 74 series of logic integrated circuits did in their original form, but subsequent ranges of improved devices bent the rules slightly. The basic type numbers of the original chips start with '74' and then have a two or three digit serial number. Much the same numbering system is used for the improved devices, but some letters are added between the '74' and the serial number (Fig.3). The additional letters indicate the family the device comes from.

Most of the families of improved '74' series chips are now, like the original devices, totally obsolete. However, some have achieved widespread use, including the 'HC' and 'HCT' families. These are respectively the standard high-speed CMOS chips, and the high-speed CMOS devices that operate at normal TTL voltage levels.

The low-power schottky range was first produced many years ago, but these chips are still in use today. The original 7420 device is therefore available as the 74HC20, the 74HCT20, and the 74LS20. The various logic families are largely incompatible, so it is essential to use the right type.

Offvolt

The standard ranges of voltage regulator chips can also have an addition to the basic type number, and this is normally a single letter. Type numbers start with '78' for positive regulators, or '79' for chips intended for operation with negative supplies. For a one-amp device, the rest of the type number consists of two digits that indicate the output voltage. For instance, the two digits are '05' for a 5V regulator and '12' for a 12V type. A +5V positive regulator is therefore a 7805 (Fig.4), and a 12V negative type is a 7912.

Fig.3. Two versions of the 74244 TTL logic device (low-power schottky above and a high-speed CMOS type below). The 74 logic families are largely incompatible, so it is important to obtain the right type

Fig.4. This is a 7805 voltage regulator. It is a positive 5V type, and the lack of any letters in the middle of the type number indicates that it is the standard 1A version

The chips that have a straightforward four-digit type number are one-amp regulators, but devices having alternative current ratings are produced. These have a letter inserted in the middle of the type number to indicate the maximum current rating. There are three widely available alternatives to the standard devices, as in Table 4:

Table 4

Letter	*Current rating*
L	0.1A (100mA)
M	0.5A (500mA)
S	2A

A component having 78L15 as its type number would, therefore, be a +15V, 0.1A voltage regulator, and one having 79M05 as the type number would be a –5V, 0.5A regulator. With regulator chips, and the 74 series logic type, the full type number will include a manufacturer's prefix, and in the case of 74 chips there will be a suffix to indicate the package type as well. However, in component catalogues you may well find that any prefix and suffix are not mentioned, and that only the basic part number is given.

STORE YOUR BACK ISSUES ON CD-ROMS

VOL 1: **BACK ISSUES** – January 1999 to June 1999
Plus some bonus material from Nov and Dec 1998

VOL 2: **BACK ISSUES** – July 1999 to December 1999

VOL 3: **BACK ISSUES** – January 2000 to June 2000

VOL 4: **BACK ISSUES** – July 2000 to December 2000

VOL 5: **BACK ISSUES** – January 2001 to June 2001

VOL 6: **BACK ISSUES** – July 2001 to December 2001

VOL 7: **BACK ISSUES** – January 2002 to June 2002

VOL 8: **BACK ISSUES** – July 2002 to December 2002

VOL 9: **BACK ISSUES** – January 2003 to June 2003

VOL 10: **BACK ISSUES** – July 2003 to December 2003

VOL 11: **BACK ISSUES** – January 2004 to June 2004

VOL 12: **BACK ISSUES** – July 2004 to December 2004

VOL 13: **BACK ISSUES** – January 2005 to June 2005

VOL 14: **BACK ISSUES** – July 2005 to December 2005

VOL 15: **BACK ISSUES** – January 2006 to June 2006

VOL 16: **BACK ISSUES** – July 2006 to December 2006

VOL 17: **BACK ISSUES** – January 2007 to June 2007

VOL 18: **BACK ISSUES** – July 2007 to December 2007

VOL 19: **BACK ISSUES** – January 2008 to June 2008

VOL 20: **BACK ISSUES** – July 2008 to December 2008

VOL 21: **BACK ISSUES** – January 2009 to June 2009

VOL 22: **BACK ISSUES** – July 2009 to December 2009

FIVE YEAR CD-ROM No.1 – Jan '03 to Dec '07

FIVE YEAR CD-ROM No.2 – Jan '04 to Dec '08

FIVE YEAR DVD-ROM No.3 – Jan '05 to Dec '09

NOTE: These DVD/CD-ROMs are suitable for use on any PC with a DVD/CD-ROM drive. They require Adobe Acrobat Reader (available free from the Internet – **www.adobe.com/acrobat**)

WHAT IS INCLUDED

All volumes include the *EPE Online* editorial content of every listed issue, plus links to all the available **PIC Project Codes** for the PIC projects published in those issues. **Please note that we are unable to answer technical queries or provide data on articles that are more than five years old. Please also ensure that all components are still available before commencing construction of a project from a back issue.**

A great way to buy *EPE* Back Issues – our DVD/CD-ROMs contain back issues from our *EPE* Online website plus bonus articles, all the relevant PIC software links and web links. Note: no free gifts are included.

Order on-line from
www.epemag.com (go to the UK store or US store) or by phone, fax, email or post

BACK ISSUES DVD/CD-ROM ORDER FORM

Please send me the following Back Issue DVD/CD-ROMs.

Volume Numbers:...

....

Price £16.45 each, £29.95 for Five Year DVD/CD-ROMs – includes postage to anywhere in the world.

Name ....

Address ....

....

....

Post Code...

☐ I enclose cheque/P.O./bank draft to the value of £ ....

☐ please charge my Visa/Mastercard/Maestro £ ....

Card No. ....

Card Security Code .... (The last 3 digits on or just under the signature strip)

Valid From................ Expiry Date ....

Maestro Issue No...........

Maestro MasterCard VISA

SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.**

Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.

Normally posted within seven days of receipt of order.

Add Wired and Wireless Connectivity to Your Design

Microchip Offers Easy-to-use, Upgradable Product Solutions

Anglia and Microchip offer support for a variety of wired and wireless communication protocols, including peripheral devices and solutions that are integrated with a PIC® Microcontroller (MCU) or dsPIC® Digital Signal Controller (DSC).

Microchip's Solutions include:

USB
8-, 16- and 32-bit USB MCUs for basic, low-cost applications to complex and highly integrated systems along with free license software libraries including source code.

Ethernet
PIC MCUs with integrated 10/100 Ethernet MAC, standalone Ethernet controllers and EUI-48™/EUI-64™ enabled MAC address chips.

CAN
8-, 16- and 32-bit MCUs and 16-bit DSCs with integrated CAN, stand-alone CAN controllers, CAN I/O expanders and CAN transceivers.

LIN
LIN Bus Master Nodes as well as LIN Bus Slave Nodes for 8-bit PIC MCUs and 16-bit dsPIC DSCs. The physical layer connection is supported by CAN and LIN tranceivers.

WiFi®
Innovative wireless chips and modules allowing a wide range of devices to connect to the Internet. Embedded IEEE Std 802.11 Wi-Fi transceiver modules and free TCP/IP stacks.

ZigBee®
Certified ZigBee Compliant Platform (ZCP) for the ZigBee PRO, ZigBee RF4CE and ZigBee 2006 protocol stacks. Microchip's solutions consist of transceiver products, PIC18, PIC24, and PIC32 MCU and dsPIC DSC families, and certified firmware protocol stacks.

MiWi™
MiWi and MiWi P2P are free proprietary protocol stacks developed by Microchip for short-range wireless networking applications based on the IEEE 802.15.4™ WPAN specification.

GET STARTED IN 3 EASY STEPS

1. Register for a free evaluation board at*: www.anglia.com/microchip/
2. Register for a free seminar at**: www.anglia.com/events/
3. Order samples www.microchip.com/connectivity

MCP2200 USB-to-Virtual Communications Port Demo Board (Part # MCP2200EV-VCP)

* - First 100 registrations only
** - Subject to qualification & availability

BY IAN BELL

Input and output impedance

LAST month, we started looking at a question posted by *EPE Chat Zone* user ***atferrari*** on output impedance.

I am trying to grasp properly the concepts of output impedance and input impedance. Regarding the first, I think I have a minimal idea, but trying to calculate it in a real case, I fail miserably. For the attached circuit [Fig.1] I need to know the source impedance.

My questions:

a) Given the filter, what is the source impedance? Can you tell briefly how do you calculate (or just estimate) it?

b) If I apply V_{out} (as V_{sig}) to the resistive divider, what is the source impedance at the output where I get V_{div}? Can you tell again, how do you calculate (or just estimate) it?

Previously, we discussed some of the theory behind the concept of output impedance – Thévenin and Norton's theorems, equivalent circuits and small signal analysis. Using this, we were able to answer atferrari's second question: if the output impedance of the filter stage is very small (compared with R3), then the output impedance after the divider is equal to the parallel resistance of R3 and R4. If the filter output impedance cannot be ignored, we can add it to R3 and again take the parallel combination.

The first question is a little ambiguous – if it refers to the source driving V_{in} then the question cannot be answered because no details of the source were provided. However, we will assume the question refers to the output impedance of the filter; this is something we can address and leads to some interesting insights about the performance of this circuit.

Filter output impedance

Finding the output impedance of the filter is more complex than considering the divider driven by a known voltage source (which is what we did last month). This is because we have a feedback circuit – the op amp will have its own output impedance, but the output impedance of the whole filter circuit will be different from this due to the feedback.

Atferrari uses the CA3140, which is a BiMOS op amp with MOSFET input and bipolar output stages. The CA3140 can operate on supply voltages from 4V to 36V, using either a single or dual supply. The output stage includes built-in protection against damage due to short circuits to either supply rail or to ground – we will comment on this aspect of the output later. The datasheet value for the CA3140's output resistance is 60Ω, but the feedback means that the filter will have much lower output impedance, at least at low frequencies.

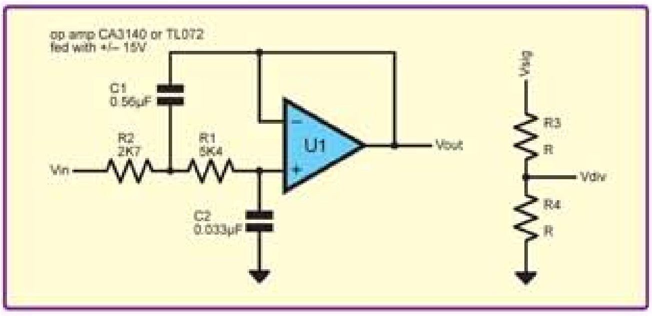


Fig.1. Copy of atferrari's circuit diagram

Feedback

Fig.2 shows a standard op amp inverting amplifier, which like the filter, is a feedback circuit. We will look at this circuit initially as it is more straightforward than the filter.

The op amp in Fig.2 is shown with an equivalent circuit representation for its internal circuitry inside its symbol – a Thévenin voltage source (voltage Av_{id}) and output resistance (R_O). Here A is the op amp's open loop (no feedback) voltage gain, V_{id} is the op amp's differential input voltage, as shown on the schematic, and R_O is the op amp's open-loop output resistance (eg, as quoted on the datasheet).

We can analyse the whole amplifier circuit and represent it as an equivalent circuit too, as shown on the right in Fig.2, but we will skip the calculations and just quote the result. The output resistance of the inverting amplifier circuit as a whole, R_{out} (see Fig.2) is related to the output resistance of the op amp, R_O, by:

$$R_{out} = \frac{R_O}{1+\beta A}$$

where A is the open loop gain of the op amp and β is the feedback fraction, that is the proportion of the output signal that is fed back to the op amp's inverting input.

The feedback is applied via the potential divider formed by R1 and R2, so the value of β is given by the potential divider formula for R1 and R2:

$$\beta = \frac{R1}{R1 + R2}$$

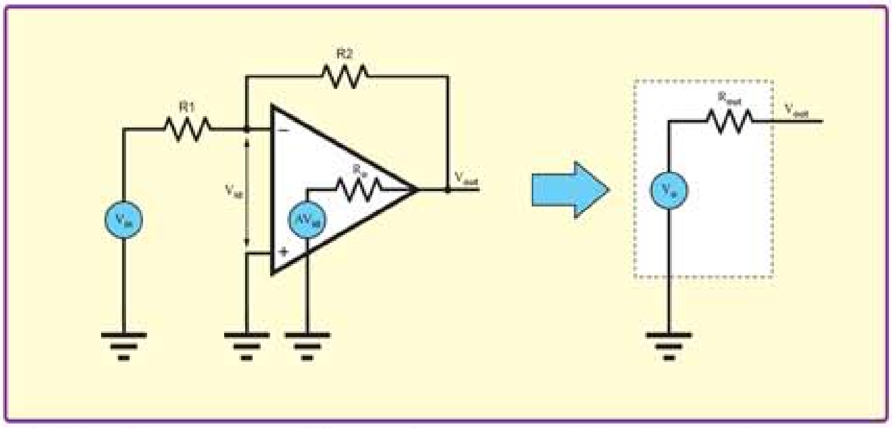


Fig.2. Inverting op amp amplifier showing op amp output resistance, R_O, and equivalent circuit for the complete amplifier with output resistance R_{out}

For an inverting amplifier circuit (Fig.2) with a gain of, say, 100, with R1 = 1k and R2 = 100k we have β = 1/101 = 0.0099. For a typical open loop gain of 100000 for the CA3140 (quoted as 100kV/V on the datasheet) the output impedance is less than a tenth of an ohm:

$$R_{out} = \frac{60}{1 + 0.0099 \times 100000} = 0.06\Omega$$

Within limits

In atferrari's filter, 100% of the output is fed back (the output of the op amp is connected directly to its inverting input). So we have β = 1, which gives an output impedance of 600$\mu\Omega$ using the same op amp parameters as before.

This small output impedance does not mean that the op amp can deliver huge currents into small loads or short circuits. A misunderstanding of the equivalent circuit in Fig.2 might indicate that, for example, the op amp would deliver 200A into a short circuit if the output was at 12V (using the 0.06Ω impedance from above: 12/0.06 = 200).

Of course, the op amp cannot handle anything like this current. The datasheet for the CA3140 quotes the short circuit output current at 40mA sourcing, and 18mA sinking.

The equivalent circuit is a small signal model which is only valid for very small signals which do not significantly shift the operating points of the active devices (eg, transistors) in the op amp. Also, the equivalent circuit only applies when the op amp's output voltage is within its normal output operating range.

Once a circuit has been pushed into a non-linear region of operation, the small signal output impedance no longer applies. Non-linear conditions include clipping, saturation and the activation of any output protection/current-limiting circuits.

Some protection

Most op amps have output short-circuit protection, which allows the output to be shorted to ground or the supplies without damaging the chip. The protection circuitry monitors the current flowing in the output and turns off the output transistor(s) if the current exceeds some pre-defined limit.

Typically, the current detection is achieved by using a small resistor in the output signal path, and a transistor is used to switch off the output transistor(s) (eg, by shorting the base and emitter). This switching is non-linear and the small signal model does not apply once the short circuit protection is on.

As we saw earlier, negative feedback improves the output impedance of the inverting amplifier compared with the op amp from which it is made.

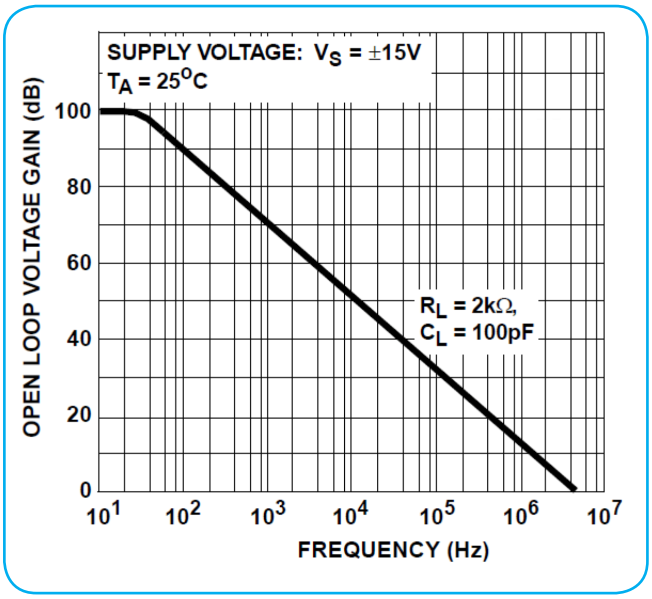


Fig.3. Open-loop frequency response of the CA3140 op amp; from the Intersil datasheet (www.intersil.com).

In general negative feedback improves input and output impedance by the factor (1+ βA). The inverting amplifier is a voltage output amplifier, so the output impedance is reduced by (1+ βA), making it closer to an ideal voltage source.

Applying negative feedback to a current output amplifier will increase the output impedance by (1+ βA), making it closer to an ideal current source. Similarly, the input impedance of a voltage-input amplifier is increased, and the input impedance of a current-input amplifier is decreased, by negative feedback. The factor (1+βA) applies to ideal or fairly ideal circuits; op amps often come close to this, but other types of circuit may not conform closely to the assumptions used to obtain this expression.

Frequency dependence

We must also be aware that βA is frequency-dependent. As frequency increases, the open-loop gain of an op amp decreases, so the value of (1+ βA) decreases too (the frequency response of the CA3140 is shown in Fig.3).

Thus, the effect of feedback in improving output (and input) impedance reduces as frequency increases. This can lead to poor performance at high frequencies in some circuits. Unfortunately, Afferrari's filter circuit is one in which this happens.

Afferrari's circuit is a unity gain, second order, low-pass Sallen and Key filter. This filter topology was developed by RP Sallen and EL Key of Massachusetts Institute of Technology (MIT) in the 1950s, and has remained popular despite the shortcomings of its high-frequency operation.

An intuitive understanding of the filter can be helped by considering the capacitors in Fig.1 to be open circuit at low frequencies and short circuits at high frequencies. At low frequencies (with the capacitors effectively removed) the circuit is simply a unity-gain op amp buffer with the input signal connected via the resistors. The high input impedance of the op amp means that the resistors have little effect. The whole circuit is simply a unity-gain buffer.

At high frequencies, the op amp's input is shorted to ground by C2, so there is little or no signal to amplify/buffer and the output is at or close to zero. At intermediate frequencies, the detailed behaviour of the circuit depends on the specific values of the capacitors and resistors used.

LTSpice simulation

It is revealing to simulate two copies of the Sallen and Key filter in which one uses a real op amp and the other is ideal. An LTSpice schematic for such an experiment is shown in Fig.4.

We have used different component values from Atferrari's circuit to give a more straightforward low-pass response. The op amp is also different, simply the first one from the LTSpice library (LT1001). This does not matter as it is the general behaviour of the Sallen and Key circuit, rather than the specifics of particular op amps, which are of interest.

In order to simulate an ideal op amp we need to add one to our schematic. To do this, click on the component button on the toolbar and go to the Opamps folder. Select 'opamp' which is almost at the end of the list, after all the LT devices. Place the op amp symbol on the schematic. This generic symbol alone is not sufficient for simulation; LTSpice needs to be told where to find the sub-circuit simulation model.

To do this we need to add the spice directive '.lib opamp.sub'. Click on the spice directive button (the one marked '.op'), enter the text .lib opamp.sub, make sure the 'SPICE directive' radio button is selected, click OK and place the text on the schematic.

We need to run an AC analysis – this enables us to plot signal values resulting from a small AC input against frequency. First set up the signal source – right click on the Vinput voltage source (Fig.4), then in the 'Small signal AC analysis

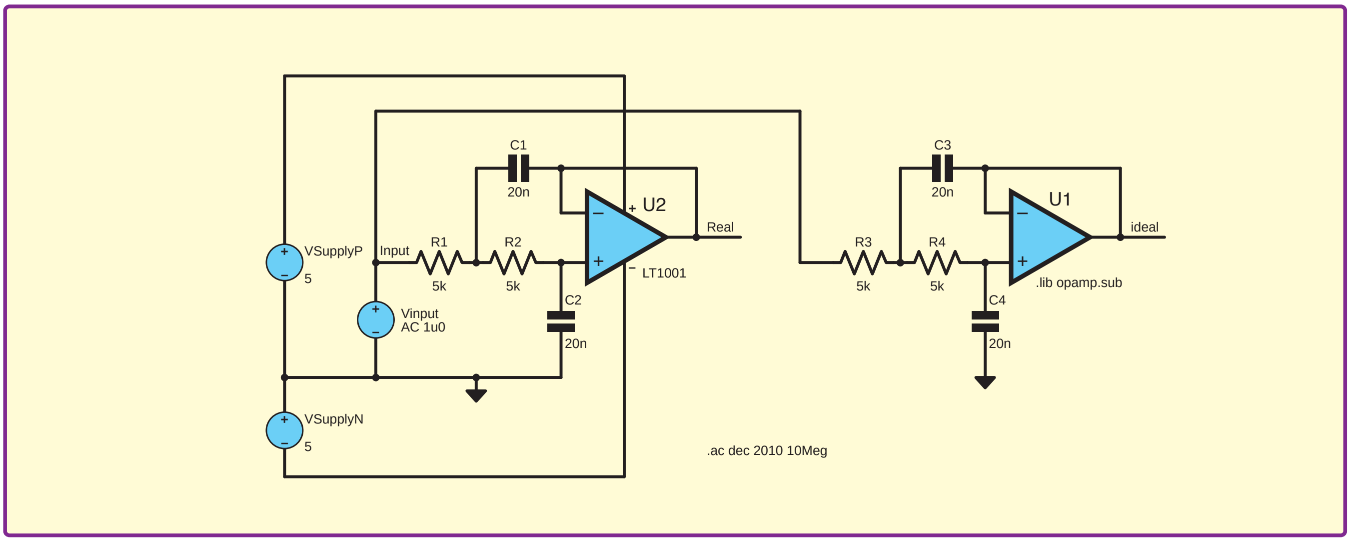


Fig.4. LTSpice schematic for comparing a real and ideal op amp in a Sallen and Key filter.

(AC)' section set the 'AC Amplitude' and 'AC Phase'. Values of 1μ and 0 respectively were used in this example.

Next, set up the simulation command: click the 'Simulation' item from the menu bar and select 'Edit Simulation Cmd'. In the window which appears, select the 'AC Analysis' tab and set the simulation parameters. The example here used: Type of sweep: Decade, Number of points per decade: 50, Start frequency: 10 and Stop Frequency: 10 Meg. Click OK.

Run the simulation. The initial waveform window will be empty. We want to plot the gain (output voltage divided by input voltage) for the two circuits. To do this, right click on the waveform window and select 'Add Trace'. In the window which appears, click on V[ideal] from the list of available data. This will appear in the 'Expression(s) to add' text box at the bottom of the window. Type a slash character (/) – the divide by symbol – directly after the signal name in the box. Then click on V[input], which will also be added to the expression box (it should read V[ideal]/V[input]). Click OK to add the curve and repeat for the real op amp output signal, V[real].

The result is shown in Fig.5. The green gain curve for the filter with the ideal op amp follows the hoped-for filter response – flat at unity gain (0dB) up to the cut-off frequency and then decreasing steadily as frequency increases. The real op amp curve follows the ideal curve closely at low frequencies, up to and past the cut-off frequency.

However, unfortunately, at high frequencies (around 100kHz in this example) the gain starts increasing again. The gain initially increases as fast as it was falling off – the circuit is behaving like a high-pass rather than a low-pass filter.

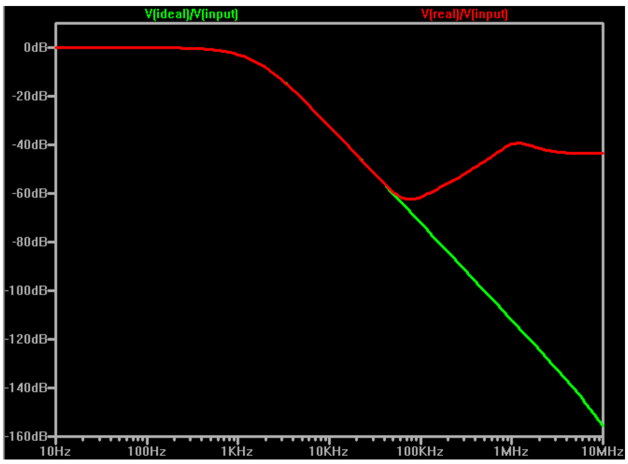


Fig.5. Simulation showing a problem resulting from op amp output impedance in a Sallen and Key filter. The green curve is the ideal response; the red curve is the response of the filter with the real op amp

Open-loop gain

From the LT1001 datasheet we find the open-loop gain at 100kHz is about 20dB (×10), so the open-loop output impedance will be reduced by a factor of 11, using (1+ βA) with β=1 and A=10. The LT1001 datasheet does not quote open-loop output impedance, but does have graphs of closed-loop output impedance from which we can infer an open-loop output impedance of around 60Ω (similar to the CA3140), and a closed-loop output impedance of around 5.5Ω at 100 kHz with 100% feedback.

At 100kHz, the 20nF capacitors in the circuit in Fig.4 have an impedance of 0.013Ω. Our assumption that the capacitors act as short circuits at high frequencies is therefore valid – their impedance is considerably smaller than the circuit resistors or amplifier output impedance. This means the op amp input will be effectively zero, and it is therefore trying to drive its output to 0V. Its ability to do this will be limited by the output impedance in the same way as any other output voltage.

Simplified versions

Fig.6 shows a simplified version of the filter circuit at high frequencies. The op amp has been replaced by a unity-gain buffer (this is the role it performs in this circuit). The capacitors are shown as short circuits, as just discussed. Given that the buffer's input is shorted to ground, the buffer's internal voltage source is producing 0V, as mentioned above. This is the same as connecting the internal side of the output impedance to ground, allowing us to further simplify the equivalent circuit to that shown in Fig.7.

Looking at Fig.7, we see that R2 and R_O are in parallel, but since R2 is at least 100 times larger than R_O we can ignore R2. Specifically R2 is 5kΩ, and the largest value of R_O is around 60Ω when no feedback output impedance reduction occurs. Thus, v_{out} is related to v_{in} by the potential divider formed by R1 and R_O. So

$$V_{out} = \frac{R_O v_{in}}{(R_O + R1)}$$

However, again, R1 is about 100 times larger than R_O, so in this case we can ignore R_O in the sum of the resistances, giving an approximate value of v_{out} as:

$$V_{out} = \frac{R_O}{R1} v_{in}$$

Getting real

The output of the real filter circuit is a combination of the unwanted signal given by the above equation and the ideal filter

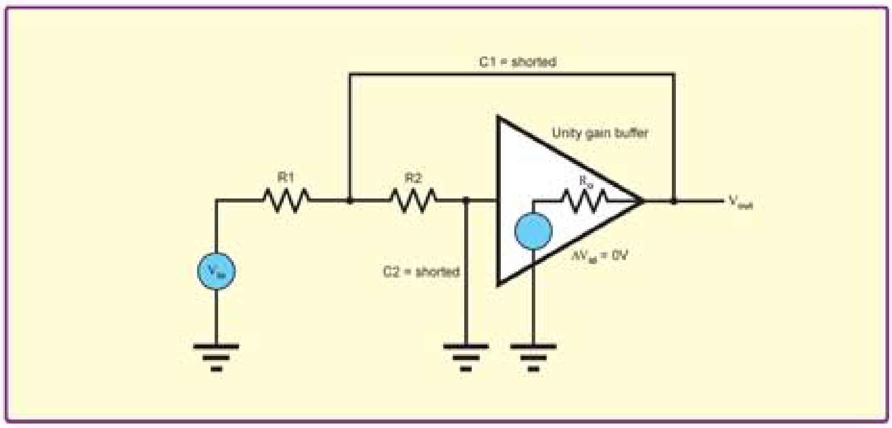


Fig.6. Simplified equivalent circuit for the filter at high frequencies

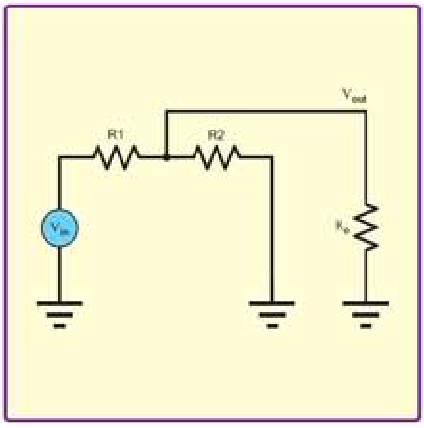


Fig.7. Further simplification of the equivalent circuit in Fig.6.

response. At low frequencies, the ideal response dominates, but as frequency increases, the op amp's gain decreases, so the effective value of R_O increases, increasing the contribution of the unwanted signal to the total output. At high frequencies, this unwanted signal dominates the circuit's output.

We noted previously that at 100kHz R_O was around 5Ω, so R_O/R1 is about 1/1000, or –60 dB relative to v_{in}. The ideal filter response is also –60dB around this frequency. This is the point at which the unwanted signal becomes significant compared to the ideal filter output. Below this frequency, the 'true' filter output is larger than the unwanted signal and the ideal and real curves are close together. We see on Fig.5 that the ideal and real curves diverge around the –60dB point at 100kHz.

At 1MHz the open-loop gain of the LT1001 has dropped to below 1, so the output impedance is getting close to the open-loop value, say around 50Ω. Thus, R_O/R1 is about 1/100, so v_{out} is 1/100 of v_{in} or –40dB relative to v_{in}. This is where we find the red curve on Fig.5. The output is dominated by this contribution. At this frequency, the ideal filter response is around –120dB, thousands of times smaller than the unwanted signal resulting from the op amp's non-ideal output impedance.

Atferrari's asked about the output impedance of his filter circuit, and it turns out that this particular filter architecture has poor performance due to the op amp's output impedance (not all types of filter do). Readers interested in a more detailed analysis of the Sallen and Key filter might like to read the report on this topic by James Karki of Texas Instruments, which includes a more detailed discussion of the output impedance problem.

Reference

James Karki, *Analysis of the Sallen-Key Architecture*, Texas Instruments Application Report, July 1999, SLOA024B. **http://www.ti.com.cn/cn/lit/an/sloa024b/sloa024b.pdf**

Max's Cool Beans

By Max The Magnificent

For a long time, I resisted the urge to purchase an iPad. My reasoning was that I already had multiple computers at work and at home, plus a netbook that sits on the couch, plus a Kindle e-Book reader, plus… the list goes on. The end result was that I found it difficult to justify splashing out more money on yet another computer.

What a fool I was. I'm now a total iPad convert. This all came about a couple of months ago when I attended a conference in California and saw the little rascals all over the place. People were using them to take notes and photos and send messages and all sorts of things.

Later, on the flight back, scrunched up with my knees wrapped around my ears in my economy seat, there was no way I could work on my 17-inch laptop because there was no room for it. Meanwhile, the guy sitting next to me was working happily away on his iPad.

On my return, I mulled things over for a couple of days and then decided to take the plunge. I bounced over to my local Apple store and picked up a 64GB iPad 2 (I opted for the Wi-Fi only version as opposed to Wi-Fi + 3G and, so far, I have no reason to regret this choice). Now, I cannot imagine life without my iPad.

Fun and Games

Purely on the personal front, I've found that the iPad is a fantastic tool for storing and presenting photos and videos. I'm going to visit my dear old mum in England in the not-so-distant future, and I know that she is going to be blown away by the quality of the images of my home and family in America, as displayed on the iPad.

Also, I have to say that, although I'm really not much of a computer games player, when you have an iPad coupled with over 70,000 applications available in the app store – many of them free – it seems a shame not to try a few out (just to evaluate the user experience, you understand).

On this basis, I totally recommend one app called Cave Bowling ($0.99 as I pen these words); you can lose hours playing this strangely addictive program. But life (and the iPad) is not all fun and games – there's also the professional side of things to consider, which leads us to…

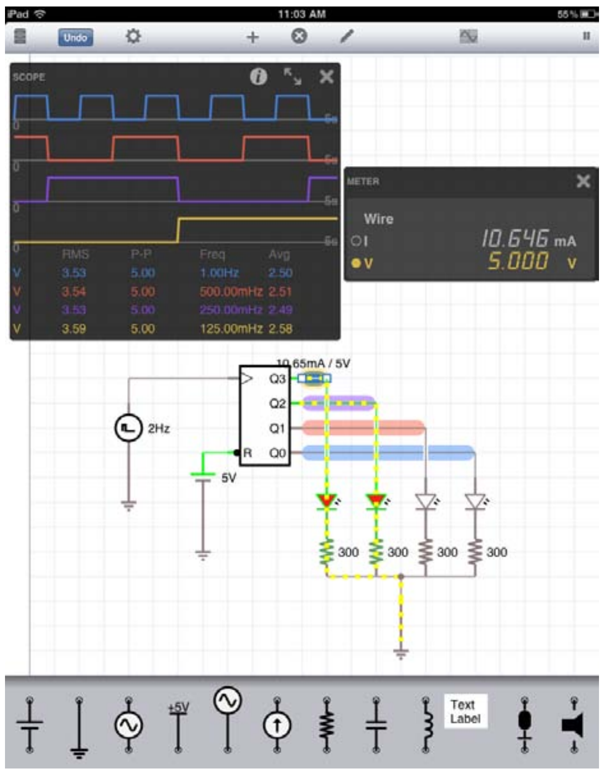
iCircuit

iCircuit (**http://icircuitapp.com**) is a really clever circuit editor and simulator. Although it costs $9.95, this little rascal is more than worth the money. Perhaps the best way to start is to look at the screenshot I just took – see opposite.

This is a demo circuit that comes with the app (there are a bunch of such circuits), but it's really easy to create your own. All you do is use your finger to drag components from the toolbar at the bottom and place them where you wish on the page. Only a few of the available components are shown in this screenshot, but in fact you have signal generators, voltage sources, and current sources; resistors, capacitors, and inductors; diodes and transistors (bipolar and field-effect); logic gates (AND, OR, NAND, NOR, XOR) and registers (JK and D-type flip-flops); digital-to-analogue and analogue-to-digital converters... the list goes on. Also, you have more sophisticated elements like 555 timers and a 3-axis accelerometer (which actually reflects the real-world signals from the 3-axis accelerometer in the iPad).

Once you've placed a few components, you can use your finger and the wire tool to draw wires and connect the components together. One unusual aspect to this app is that the simulator is always running in the background, so as soon as you start placing components you can also start analysing your circuit. Clicking on a wire brings up the multimeter (the smaller gray box shown in the upper-right of the screenshot). Clicking the voltage and/or current buttons associated with the signal in the multimeter causes them to be displayed on the oscilloscope (the larger gray box shown in the upper-left of the screenshot).

Another nice feature is that a wire's colour reflects its voltage value and animated dots moving on the wires reflect current flow. This really is a great tool to learn electronics; play with simple digital and analogue circuits; and understand what's going on. I would say that it's highly recommended for anyone who is interested in electronics, including students, hobbyists, and engineers. In fact, I'm just thinking how useful this would have been when I started playing with electronics when I was 14 years old. Can you imagine people's faces if I could somehow take my iPad back through time to the 1970s?



iCircuit screen-grab

EPE EXCLUSIVE

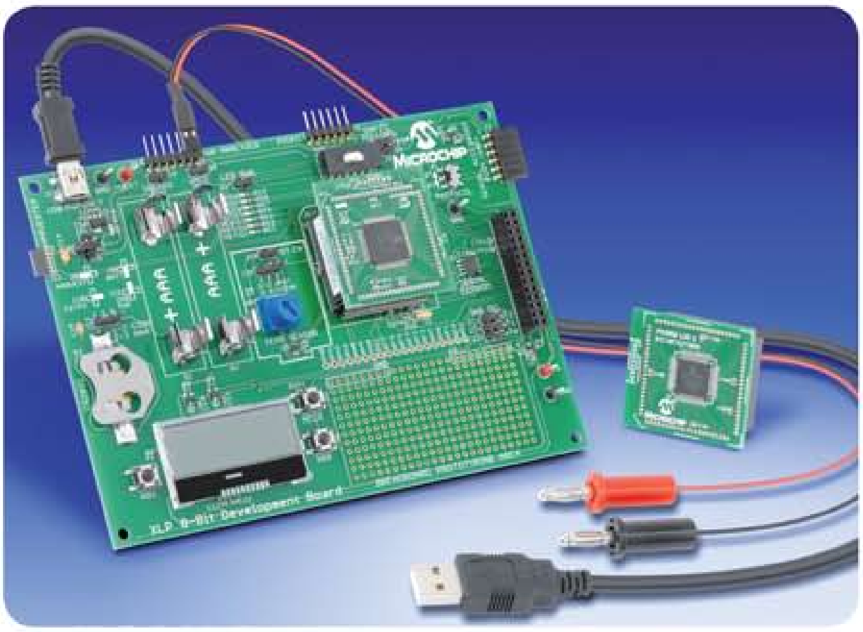
Win a Microchip XLP 8-Bit Development Board

EVERYDAY PRACTICAL ELECTRONICS is offering you the chance to win a Microchip XLP 8-Bit Development Board (DM240313). The XLP 8-bit Development Board provides a low-cost, highly configurable development system for Microchip's new line of extreme-low-power 8-bit PIC18F or PIC16F Enhanced core microcontrollers that allow for the design of sleep currents down to 20nA.

The board supports development for the PIC18F87K22 or PIC16LF1947 MCUs, which highlight the capabilities of each product family. It can be powered by five different power sources, including batteries or energy harvesting modules (sold separately), and it supports a variety of common components that can be selectively enabled. The board is also expandable through the on-board PICtail connector that permits the addition of capabilities such as RF connectivity. The kit includes a USB cable, a Power Measurement cable, a Quick Start guide and a PIC16LF1947 PIM.

The board is suitable for prototyping many low power applications, including RF, temperature sensors, electronic door locks, LCDs, remote controls, security sensors, smart cards, and energy harvesting. The PICtail interface supports Microchip's extensive line of daughter cards for easy evaluation of your next low power application.

BOARD FEATURES



- PIC18F87K22 (128KB Flash, 80-pin PIM) installed
- Supports other PIC16LF1947 (28KB Flash, 64-pin PIM) Separate/ Unprogrammed
- Current measurement terminals allow device or board-level current measurements
- Expansion connector accessing full device pinout and breadboard prototype area
- Convenient connections for MPLAB PICkit 3, ICD 3 or REAL ICE for in-circuit programming and debugging
- USB interface for power and PC communication
- 24AA256 low power (100nA sleep, 1.7V Vdd) SPI serial-EEPROM
- Potentiometer (connected to 10-bit A/D, analogue input channel)
- Analogue output temperature sensor and CTMU-based diode temperature sensor
- LEDs for indication
- Power options: AAA, CR2032, energy harvesting, USB, external, or 9V power supply

WORTH $125.00 (approx. £79.00) EACH

HOW TO ENTER

For your chance to win a Microchip XLP 8-Bit Development Board, visit: **www.microchip-comps.com/epe-8bitxlp**

CLOSING DATE

The closing date for this offer is 30 December 2011

EVERYDAY PRACTICAL ELECTRONICS BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past five years are available. An *EPE* index for the last five years is also available at **www.epemag.com**. Where we are unable to provide a back issue a photocopy of any one article (or one part of a series) can be purchased for the same price. Issues from Jan. 99 are available on CD-ROM or DVD-ROM – and back issues from recent years are also available to download from **www.epemag.com**. Please make sure all components are still available before commencing any project from a back-dated issue.

DID YOU MISS THESE?

BACK ISSUES ONLY £5.00 (each inc. UK p&p.)

Overseas prices £5.80 each surface mail, £6.80 each airmail.

We can also supply issues from years: 2006 (**except** Jan., Feb., Mar., Apr., May, July). 2007 (**except** June, July, Aug), 2008 (**except** Aug, Nov, Dec) 2009 (**except** Jan, Mar, Apr.). 2010 (**except** May, June, July, August, Oct, Nov, Dec). Where we do not have an issue a photocopy of any ***one article*** or ***one part*** of a series can be provided at the same price.

OCT '10 (PHOTOCOPIES ONLY)

PROJECTS • Railpower IV – Part 1 • Bridge Adaptor For Stereo Power Amplifiers • LED Strobe and Tachometer – Part 1 • CDI Module For Small Petrol Motors • Ingenuity Unlimited

FEATURES • Techno Talk • Recycle It! • Circuit Surgery • PIC N' Mix • Max's Cool Beans • Interface • Net Work – The Internet Page.

NOV '10 (PHOTOCOPIES ONLY)

PROJECTS • USB Clock with LCD Readout – Part 1 • Microphone Preamp for PCs and MP3 Players • LED Strobe and Tachometer – Part 2 • Railpower IV – Part 2 • Ingenuity Unlimited

FEATURES • Teach-In 2011 –A Broad-Based Introduction to Electronics – Part 1 • Techno Talk • Recycle It! • Circuit Surgery • Practically Speaking • Net Work – The Internet Page.

DEC '10 (PHOTOCOPIES ONLY)

PROJECTS • Digital RF Level & Power Meter • Multi-Purpose Car Scrolling Display – Part 1 • 12V Speed Controller or 12V Lamp Dimmer • USB Clock with LCD Readout – Part 2

FEATURES • Teach-In 2011 –A Broad-Based Introduction to Electronics – Part 2 • Recycle It! • Techno Talk • Circuit Surgery • PIC N' Mix • Interface • Max's Cool Beans • Net Work – The Internet Page.

JAN '11

PROJECTS • USB-sensing Mains Power Switch • 433MHz UHF Remote Switch • AM (MW) Broadcast Band Loop Antenna • Multi-Purpose Car Scrolling Display – Part 2

FEATURES • Teach-In 2011 – A Broad-Based Introduction to Electronics – Part 3 • Techno Talk • Circuit Surgery • Max's Cool Beans • PIC N' Mix • Practically Speaking • Net Work – The Internet Page.

FEB '11

PROJECTS • Time Delay Photoflash Trigger • Tempmaster Mk.2 • Multi-Purpose Car Scrolling Display – Part 3 • Ingenuity Unlimited

FEATURES • Teach-In 2011 – A Broad-Based Introduction to Electronics – Part 4 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work – The Internet Page.

MAR '11

PROJECTS • New, Improved Theremin • Low-Cost Digital Audio Millivoltmeter • GPS Synchronised Clock • Manual 2-Way USB Device Switch

FEATURES • Teach-In 2011 – A Broad-Based Introduction to Electronics – Part 5 • Techno Talk • Circuit Surgery • Max's Cool Beans • PIC N'Mix • Practically Speaking • Net Work – The Internet Page.

APR '11

PROJECTS • 45-Second Voice Recorder Module • Multi-Function, Intelligent Remote-Controlled Dimmer • PIR-Triggered Mains Switch • A Quick 'N' Easy Digital Slide Scanner • Ingenuity Unlimited

FEATURES • Teach-In 2011 – A Broad-Based Introduction to Electronics – Part 6 • Techno Talk • Circuit Surgery • PIC N'Mix • Max's Cool Beans • Interface • Net Work – The Internet Page.

MAY '11

PROJECTS • The μCurrent • Digital Audio Oscillator • Build A 6-Digit GPS Clock – Part 1 • Simple Voltage Switch For Car Sensors • Ingenuity Unlimited

FEATURES • Teach-In 2011 – A Broad-Based Introduction To Electronics – Part 7 • Techno Talk • Recycle It! • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work – The Internet Page.

JUNE '11

PROJECTS • High Performance 230V AC 10A Full-Wave Motor Speed Controller • Precicion 10V DC Reference For Checking DMMs • Build A 6-Digit GPS Clock – Part 2 • Musicolour IRDA Accessory

FEATURES • Teach-In 2011 – A Broad-Based Introduction To Electronics – Part 8 • Techno Talk • Circuit Surgery • PIC N'Mix • Max's Cool Beans • Interface • Net Work – The Internet Page.

JULY '11

PROJECTS • Metal Locater • Multi-Function Active Filter Module • Beam-Break Flash Trigger • Loop Antenna and Amplifier • Converting UNIDEN Scanners For AIS • Ingenuity Unlimited

FEATURES • Teach-In 2011 – A Broad-Based Introduction To Electronics – Part 9 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work – The Internet Page.

AUG '11

PROJECTS • SD Card Music and Speech Recorder/ Player • Deluxe 3-Channel UHF Rolling Code Remote Control – Part 1 • Input Attenuator For The Digital Audio Millivoltmeter

FEATURES • Teach-In 2011 – A Broad-Based Introduction To Electronics – Part 10 • Techno Talk • PIC N' Mix • Circuit Surgery • Interface • Max's Cool Beans • Net Work – The Internet Page.

SEPT '11

PROJECTS • Digital Megohm and Leakage Current Meter • Build a High-Quality Stereo DAC For Superb Sound From Your DVD Player – Part 1 • Deluxe 3-Channel UHF Rolling Code Remote Control – Part 2 • Auto-Dim Add-On For The 6-Digit GPS Clock • Ingenuity Unlimited

FEATURES • Teach-In 2011 – A Broad-Based Introduction To Electronics – Part 11 • Recycle It! • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work – The Internet Page.

OCT '11

PROJECTS • Twin Engine SpeedMatch Indicator • Wideband Air-Fuel Mixture Display • Build a High-Quality Stereo DAC For Superb Sound From Your DVD Player – Part 2 • Open-USB-IO: A Universal I/O Solution

FEATURES • Techno Talk • Interface • Circuit Surgery • Max's Cool Beans • Net Work – The Internet Page.

ORDER FORM – BACK ISSUES – PHOTOCOPIES– INDEXES

☐ Send back issues dated ....

☐ Send photocopies of (article title and issue date) ....

Name ....

Address ....

.... Tel: ....

☐ I enclose cheque/P.O./bank draft to the value of £ ....

☐ Please charge my Visa/Mastercard/Maestro £ ....

Card No .... Maestro Issue No ....

Valid From .... Card Expiry Date .... Card Security Code ....
(The last 3 digits on or just under the signature strip)

SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.**

Tel: 01202 880299. Fax: 01202 843233.

E-mail: orders@epemag.wimborne.co.uk **On-line Shop**: www.epemag.com

Payments must be in £ sterling – cheque or bank draft drawn on a UK bank. Normally posted within seven days of receipt of order. Send a copy of this form, or order by letter if you do not wish to cut your issue. M11/11

NET WORK

by Alan Winstanley

HP swallows the tablet

I'M NOTORIOUS at *EPE* HQ for being a 'Last-minute Larry' when it comes to submitting my *Net Work* copy, but when writing a topical monthly column I hold on until the very last minute in order to check out any late-breaking news. (Sorry, ed) A month can be a long time in technology: in September's *Net Work* I summarised some of the latest developments in the tablet market, with new 10-inch tablets being launched by HP, Samsung, Blackberry and others. Tablets are becoming an extremely slick way of accessing the web, email or running applications.

No sooner had *Net Work* gone to press than HP floated a raft of price reductions, which were short lived, because soon afterwards HP announced that it was pulling the plug on its brand-new Touchpad tablet altogether. In a market dominated by the formidable and expensive Apple iPad, even an industrial monolith like HP could not make the numbers add up and they took the astonishing step of announcing their withdrawal from the tablet market soon after the Touchpad's debut.

HP's Touchpad tablet – when it's gone, it's gone!

Surprisingly, after glacial levels of sales risked leaving HP with a moraine of unsold stock, HP's WebOS-based Touchpad (dubbed 'Ouchpad' in the US) has been flying off the shelves ever since. Enthusiasts are scooping them up at knock-down prices hoping to hack into the Linux-based WebOS to customise them. HP promises to support its WebOS users post-sale, but Amazon UK is already slashing 37.5% off the price, so make the most of these very interesting-looking devices while you can.

The tablet form factor is the logical choice for a user-friendly portable 'sealed unit' display having no moving parts at all. In a further twist, Apple is busily suing Samsung for allegedly aping the look and feel of iPads in the shape of Samsung's Galaxy smartphones and tablets (see September *Net Work*). Apple is battling to have Samsung's rounded rectangles removed from shelves across Europe. Samsung retorts that the tablet is not new (claiming that technically, it's 'prior art') and for starters cites their appearance in the movie *2001: A Space Odyssey* – you can judge for yourself in a movie clip at **http://youtu.be/JQ8pQVDyaLo**.

There are downloadable apps for virtually everything, and tablets are fast becoming the choice for consumers and trendy businesses everywhere. Even local authorities, such as Bury Council, are considering equipping their fleet of garbage vehicles with £9,000 ($14,000) worth of iPads, to help their operators with navigation and data collection.

For casual surfing and email, tablets may suit many consumers, but for surfing, authoring and dinking around, I'm sticking with a Sony laptop with its built-in clattery keyboard and replaceable battery. It's bulkier, but I can type very quickly, it runs Flash natively (unlike an iPad) and I can replace its worn-out battery for a new one with no bother. It helps me run the *EPE Chat Zone* forum with distinction, and I could even repair its DC inlet if needed. (*EPE* readers might enjoy my personal step-by-step guide to repairing a laptop DC jack, with photos at **http://www.epemag.net/laptop-repair.htm**).

The fact that HP is slashing a new range so soon, and that Apple is going to extraordinary lengths to keep a grip on the segment, illustrates just how volatile this topsy-turvy market is, with Apple's position seemingly impregnable, helped in no small way by the iPad's carefully nurtured hype and its highly impressionable target audience.

Racing ahead

Nevertheless, it's the 'son of tablet' or smartphone market that is really racing ahead, with one-in-three Americans now owning such a mobile device, and for some users they are the sole means of accessing the Internet. Google has bought Motorola's Mobility smartphone business for $12.5 billion, which will give Google a major platform to offer Android-based mobile smartphones of its own. (Recall from previous columns that the Chromebook, initially made by Samsung and Asus, is an always-on mini laptop using Google's Chrome OS. Unlike a laptop or netbook, they do not run applications natively, but rely on the Internet to access cloud-based applications such as email instead.)

Motorola is already slating new Android product launches starting with the Motorola 'Cliq' ('Dext', outside the USA) smartphone out now, which claims to consolidate and sync contacts and social networking like never before, thanks to a reincarnation of Motorola's 'Motoblur' front-end. See **http://tinyurl.com/owvjtg or http://tinyurl.com/3dude5t** (UK) for a Flash-based demo. Screenshots show a blizzard of widgets, icons and webcam images, which will be paradise for a busy mobile social networker or MP3 lover.

'Smarter' doesn't necessarily mean better, though; it has become apparent over time that modern smartphones

can be less sensitive than their older 2G brethren, partly because there is less space available for the internal antenna. The iPhone launch backfired horribly due to a torrent of complaints about poor reception and antenna problems. And in many localities you still cannot enjoy a 3G signal, which makes the latest bells-and-whistles smartphones irrelevant for many users. My much older Orange SPV phone was good enough for a lengthy radio interview when my new HTC Tytn smartphone would have left me literally speechless, and I have never been able to make a mobile video call in my life.

Business beware

While mobile Internet access is still a pedestrian experience (in more ways than one) for many, there is a new generation of users for whom Googling online, updating Facebook or using eBay via a smartphone are completely automatic tasks. Many are elbowing their PCs and laptops into second place in favour of mobile Internet usage.

Motorola's latest Smartphones promise Internet users a social networking nirvana, thanks to its Motoblur interface

More worryingly, business users are utilising their phone both for business and private purposes, and the distinction between the two is blurring. Speaking from experience, I would never entrust my whole diary, to do list, phone book and email into one mobile device, because it would be a catastrophe if it were lost, stolen or broke down, but consumers seem to place a lot more faith than I have in a single integrated device that will allow them to run their entire lives for them.

A business mobile phone can contain all sorts of commercially sensitive emails, photos or data, as well as the owner's personal information, which will be of use to identity thieves. This makes mobile security even more important. Smartphones have until now largely escaped threats from malware or viruses, but it is only a matter of time before damage is inflicted on corporate data due to mobile malware finding its way onto a phone.

With so many apps being produced for mobile platforms, including Android, Symbian and Apple iOS, it's easy for complacent users to sleep-walk into downloading an infected application. A major point of difference between Apple and, say, Android apps is that Apple apps are centralised and quality-controlled: buy an Apple app and you're bounced straight to the iTunes website, but Android apps may be downloaded from Android Market (**https://market.android.com**) or innocently sideloaded from a third party website, says McAfee in its white paper *'Downloading from Mobile App Stores Is a Risky Business'*.

This vulnerability has the potential for legitimate Android applications being hacked into and resold. Currently, hackers are targeting Android apps the most, reports McAfee; the Android Geinimi Trojan has been found in the wild, and it sends the phone's full technical data, including GPS co-ordinates, back to the criminals.

Presently, iPhones are considered to be much more immune to worms or viruses, but as McAfee goes on to say in a further report on mobile security (**www.mcafee.com/us/resources/reports/rp-cylab-mobile-security.pdf**), 'devices are no longer consumer devices or business devices. They are both. Mobile security needs to be incorporated into the device and the network.'

While major mobile threats have been avoided so far, whatever type of smartphone you adopt, having so much corporate or private mobile data rolled into one device offers a happy hunting ground for potential hackers that cannot be ignored for much longer. Reputable mobile anti virus products are available from McAfee (as a business product – they don't target the Mobile consumer user at all!), Kaspersky, F-Secure, Panda and others. Now may be the time to start shopping around.

That's all for this month's *Net Work*. I'm always delighted to hear from readers by email to: **alan@epemag.demon.co.uk** . I read every mail and I'm sorry if I cannot promise to reply individually. You can also write to the editor at: **editorial@wimborne.co.uk** for possible inclusion in *Readout*.

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? **Drop us a line!**

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

King Rat!

Dear editor
How would you like to salvage up to 90% of all parts of discarded electrical equipment for pennies?

While trying to recover components I tried the usual methods: solder sucker, desoldering braid… but none of these methods appeared to work well.

So, I experimented until I found the satisfying method described below. Now, I am addicted to clearing out all the circuit boards that I have kept; such as old CD players, amplifiers and video cards, all of which were stacked in boxes, just waiting for reuse. Now I can store components, not boards, which not only saves space, but also means items are ready for quick use.

Recycling this way makes electronics cheaper, and more enjoyable, especially with the cost of components going up all the time. I have saved hundreds of pounds by reusing crystals, capacitors, transistors, triacs, amplifiers, switches, multiple connecters and ICs – even 40-pin devices come off easily with this method.

So how do I do it? Fig.1 shows a standard board of parts, but a closer inspection showed at least half of the components appeared to be soldered on both sides. My method will salvage 60% to 80% of these parts. The tools and materials needed are simple: plaited copper wire, a pot of plumber's flux, and a soldering iron. The plaited copper wire comes from aerial cable or similar. First, strip away the aerial cable's external plastic coating. Next, pull out the inner single copper wire covered in plastic. You are now left with the copper sheathing or braiding – this is the bit you need (Fig.2).

Fig.2. Coax copper screening braid

Stretch the sheathing out and wind it onto a bobbin or any insulating device (Fig.3). In use, the copper sheathing will become very hot, this is why you need the bobbin.

Dip the free end of the wound cable into the plumber's flux and wipe most of the flux onto the sides of the tub; you need very little of it on the wire. Place the fluxed wire next to the target component's soldered pins and position your soldering iron on top of this, watch the solder run off the pins onto the copper wire. When the wire is full of solder, simply snip it off and discard it.

Fig.3. Plastic bobbin

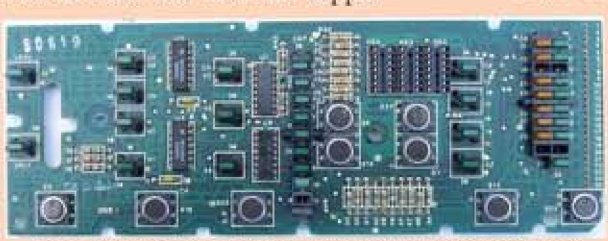


Fig.1. Harry's circuit board ready for the 'treatment'

Dip the next length of plaited wire into the flux, and off you go again.

Some boards can be tricky. If you examine a motherboard from a computer and look at the solder on the item you wish to extract, you will see the solder has gone all the way through to the other side, as though it has been soldered on both sides of the board, this makes it harder to remove unless you have a hotter iron, which can be self defeating with delicate components.

Solder on both sides requires you to use the wire on both sides of the board before you can take the component off, this means the piece will become hotter, so be careful you do not damage the item you are trying to recover.

Figure 4 shows the finished, stripped board and Fig.5 shows my haul: nine switches, 17 LEDs, three ICs. Some of the ICs had damaged pins, but these are repairable. If this had been a circuit board with soldering showing on only one side, then the ICs would probably have not been damaged.

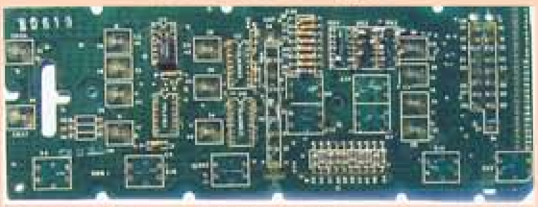


Fig.4. Stripped board minus switches, LEDs and ICs

Fig.5. Collection of salvaged parts

I have recovered a fantastic selection of components, and recommend this method to other readers.

Harry Worsley, by email

Great idea Harry; there's nothing quite like the satisfaction of building a successful project from recycled components – and the more expensive the devices you recycle, the better!

Choosing meters

Dear editor
Although I found July's *Practically Speaking* interesting, the comment on page 66 under Fig.3 is unacceptable. I have this exact device, which I purchased for under £12. It measures AC and DC up to 600V, readable with better than 0.1% error. To describe this as 'expensive' and 'limited' is a distortion of facts. I use this device every day and have found it quite invaluable and unbeatable in price and ease of use.

I'm a professional repair engineer, and I only use quality test gear, but an amateur hobbyist could not do better than use this device. I also use a similar model to that shown on page 65 for monitoring voltages over time; this type can be purchased for under £20 from specialist electronics shops.

If you want to test transistors, capacitors and resistors, then you can't beat the AVO Mk5 Model 8 (I have three) or for real precision, the range of test meters from Peak Electronics, as shown on your own inside back cover. (I also have their products.)

When it comes to analogue *vs* digital, these days, digital is usually said to be better. However, as far as I am concerned, digital never has been and never will be better!

Digital is fine for measuring millivolts for low-level adjustments and very accurate rail measurements. But I have never managed to buy a digital meter that hooked in series with mains current and which actually worked! The AVO does work and has been doing this on my bench for over 20 years. I doubt if any digital product will last this long (if the standards in the AV industry are any thing to go by).

I don't know what Mr Penfold expects from a multimeter for pennies.

Mr Douglas, by email

Robert replies:

I think that the prices quoted by Mr Douglas are a bit misleading. The meter in Fig.3 generally sells at about 35% more than the one in Fig.2, and I obtained the latter from the Far East for less than £8, including postage. As I pointed out in the article, I have used pen-style multimeters extensively, and they are very good, but a relative lack of features makes them less than ideal as a first multimeter.

The Practically Speaking *articles are written for beginners, and the advice given in them is slanted accordingly. The added features of the multimeter in Fig.2, such as transistor checking and capacitance ranges are more than a little helpful for beginners, who will probably have no other way of checking these components. The accuracy might not be all that high, but it is perfectly adequate for component testing, especially when one considers the often huge tolerances on capacitance values and transistor current gain ratings.*

Inexpensive multimeters should provide many years of service with careful amateur use, and it is probably replacement batteries that will be the main cost. I do not think that recommending beginners to buy a few hundred pounds-worth of professional quality test gear could be considered to be sound advice. The money would be better spent on building projects. Better test equipment can be obtained if and when the need arises.

Recording and CD burning in Windows 7

Dear editor
I'm contacting you from down at the bottom end of South Africa. A few weeks ago my PC went down during some horrendous rain. I'm not denying we could always do with rain, but it does sometimes have a negative effect on our electricity supply! As a result, my computer's video board 'died'. My local friendly computer shop took a look and decided I would need a new computer (I was running XP and some of my hardware was not easily renewable).

Cut to the chase, the insurance paid for a new computer – was I surprised! The new computer is nice and fast, with lots of memory; however, the operating system is Windows 7 Professional and some of my old XP programs won't run.

A friend bought to my attention an article in *EPE* from Dec 2009, which carried an article on Virtual PC written by Alan Winstanley. This was all new to me, but nevertheless, I downloaded the whole thing (nearly half a gigabyte) in a three-hour session.

Now comes the tricky bit and my reason for writing. For the old folks in town (I'm a mere 77 myself) I used to do some CD copying. I don't charge for this service, it's just nice to know that some folks out there still enjoy a lot of the old music and singers (I have some 500 CDs collected over the years).

With my previous computer, I used Steinburg CLEAN 4.0, which worked a charm running under XP. I was hoping the 'virtual' program could assist when using Windows 7. However, so far no luck, CLEAN will not even 'record'. Thus, I am stuck. If necessary I can purchase a program called 'Audio Cleaning Lab 16 Deluxe' by MAGIX, but maybe you may have some alternative leads I can follow. Steinburg say that they have not and will not be doing an update for Clean 4.0. Any suggestions would be most welcome.

Bill Jukes, by email

Alan Winstanley replies

Nice to hear from you Bill, I'm amazed that someone remembered my Net Work *article from so long ago! The Virtual PC aspect related to Windows 7 (W7) relies on it being able to pretend it's a Windows XP machine, but its success depends on hardware compatibility and not all versions of W7 support it. The situation has changed slightly since my article was written. Initially, the hardware spec was very tight, and as my PC's Intel processor does not support hardware-assisted virtualisation (HAV) I didn't do any more work on it.*

Microsoft's information is here: **www.microsoft.com/windows/virtual-pc**

I believe there is a 'compatibility mode' for running older XP programs in W7. If you would like to check your system for compatibility, Microsoft's HAV detection tool is here: **www.microsoft.com/download/en/details.aspx?displaylang=en&id=592**

For burning CDs, I'd try either of the following programs:

CD Burner XP, which is W7 compatible and available at: **http://cdburnerxp.se/en/home**

Or Imgburn, available at: **www.imgburn.com**

I use either of these when I can't be bothered opening up Nero, my preferred choice. For recording from vinyl or tape via the line in of a PC soundcard, I'd use Audacity, which is free and available from: **http://audacity.sourceforge.net/download**. *It has some useful LP recording tricks, and you can burn the recording onto audio CD with one of the above programs, or Nero.*

EPE*'s forum is free to join at* **www.chatzones.co.uk**, *where I'm sure* EPE *readers will try to help you further.*

Alan Winstanley
EPE online editor

Solder mixing

Dear editor
I have been soldering for a long time, but would like to know if it is possible to mix different kinds of solder. Typically, when making repairs or modifications, I don't know what type has been used before. Can I mix lead solder with lead-free solder, and can they be mixed with solder containing silver?

Dave Day, by email

Alan Winstanley replies

Dave, yes they can be mixed – for example, you can use silver-based solder to repair joints that are made from old lead-tin solder. So-called lead-free 'silver solder' contains a trace of copper and just a few percentage points of silver to improve performance. Although the traditional lead-type solder is outlawed for manufacturing, happily I have enough lead-tin in stock to last me a lifetime!

Ideally, try to desolder any old joints first, but generally you don't need to worry about what type of solder was used before.

Good question and thanks for asking!

Freebies for school or club

Dear editor
I am in the process of moving house and downsizing. I have a lot of electronic bits and pieces that I am sure a school or electronics club could use. I am happy to box up items, so the only cost involved would be pick up from the West Midlands, or shipping. Any interested party should get in touch with me via email: nicholson_b@sky.com.

Bob Nicholson, by email

Happy to help Bob, I'm sure there are readers who will find a good home for your surplus 'bits and pieces'.

Thank you... and more on importing from MS Excel!

Dear editor
First, I would like to say 'thank you' to you and *Peak Electronic Design* for the component analyser I received for my 'Letter of the Month' in the July 2011 issue of *EPE*. It will be very handy for these older failing eyes.

Second, with respect to the Excel logging query, I could only find an *Interface* article from October 2002 that dealt with VBA. It deals with using MSComm with VBA, not specifically inputting data directly into Excel.

I could only search back to November 1998, so there may be other articles prior to this date.

Other options, depending upon programming ability, are to use the Parallax 'PLX-DAQ' Data Acquisition for Excel' software available for free at: **www.parallax.com/tabid/393/Default.aspx** (no programming required). It does work with micros other than those from Parallax.

For those with programming ability, the following links will take you to information that should help:

http://bytes.com/topic/visual-basic/answers/553215-how-gather-data-via-rs-232-import-excel-using-vba

www.pencomdesign.com/support/relay_software/vba_software_example.htm – VBA programming example (suitable for beginners)

http://archive.msdn.microsoft.com/Caspar – Excel serial port code

http://support.microsoft.com/kb/302084 – How to automate Microsoft Excel from Microsoft Visual C#.NET

I hope the above information is useful.

Terry Mowles, by email

I'm very pleased you found the component analyser useful Terry. You have certainly been busy in solving the ever-popular Excel conundrum, which I am sure readers will find useful.

Humax PVRs

Last month, I mentioned personal video reorders (PVRs) produced by Humax. These use a hard disk to record terrestrial or satellite TV programmes and series. There is a wide range of flexible models, including Internet and Ethernet options. *EPE* reader Ken Wood wrote to me with a good tip: 'Come and join us on **http://hummy.tv** and see what you can do that isn't in the manual!'

I would recommend all Humax owners to pay a visit to this forum. I found it to be very well put together and immensely useful. Thanks to the forum I have already answered one question, how come I can record two channels and still watch a third? The whole site is a commendable effort, so 'well done everyone!' involved with it.

Alan Winstanley

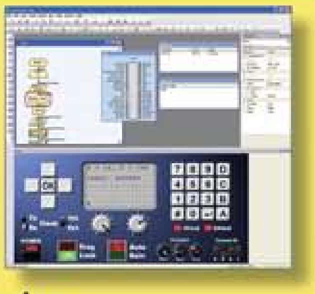
EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

FLOWCODE 4®
NO CODING, NO LIMITS...

Flowcode 4 is one of the World's most advanced graphical programming languages for microcontrollers. The great advantage of Flowcode is that it allows those with little experience to create complex electronic systems in minutes.

Flowcode's graphical development interface allows engineers to construct a complete electronic system on-screen, develop a program based on standard flow charts, simulate the system and then produce hex code for PICmicro® microcontrollers, AVR microcontrollers, ARM microcontrollers, dsPIC and PIC24 microcontrollers.

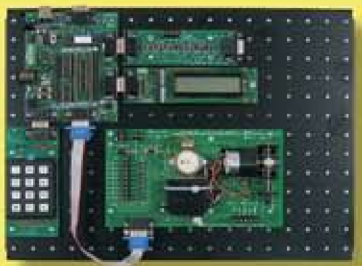


Design

Flowcode contains standard flow chart icons and electronic components that allow to you to create a virtual electronic system on screen. Drag icons and components onto the screen to create a program, then click on them to set properties and actions.

Simulate

Once your system is designed you can use Flowcode to simulate it in action. Design your system on screen, test the system's functionality by clicking on switches or altering sensor or input values, and see how your program reacts to the changes in the electronic system.



Download

When you are happy with your design click one button to send the program directly to your microcontroller based target. Targets include a wide range of microcontroller programmers, upstream E-blocks boards, the Formula Flowcode robot, the MIAC industrial controller, or your own system based on ECIO technology.

FlowKit

The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

PRICES

Prices for each of the CD-ROMs above are: ***(Order form on third page)***

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	**£45.95**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£149**	**plus VAT**
Professional and Flowkit bundle	**£175**	**plus VAT**

PICmicro TUTORIALS AND PROGRAMMING

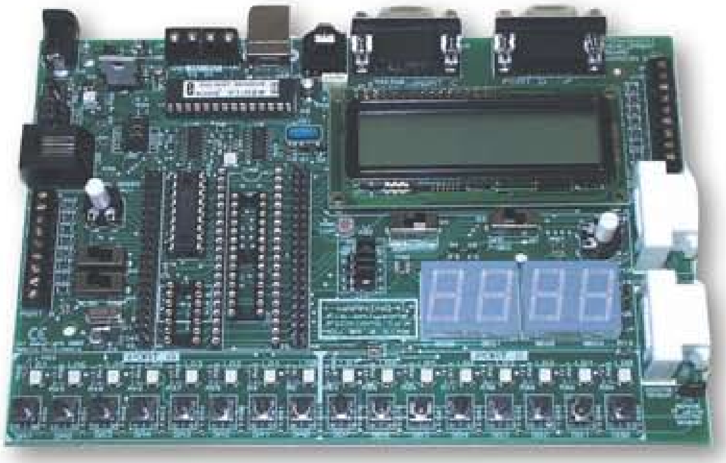
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

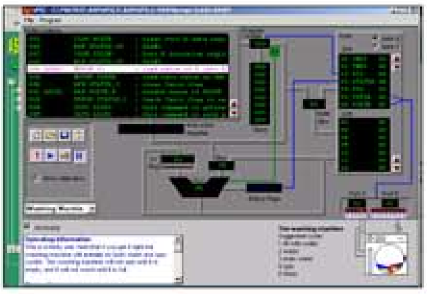
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.

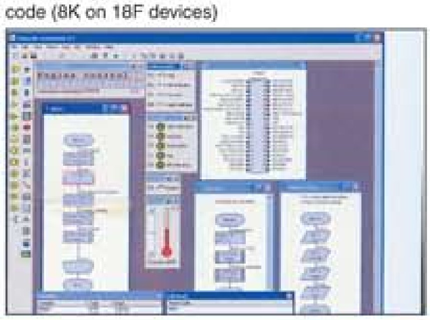
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	£45.95	inc VAT
Professional (Schools/HE/FE/Industry)	£99	plus VAT
Professional 10 user (Network Licence)	£350	plus VAT
Site Licence	£699	plus VAT
Flowcode Professional (Schools/HE/FE/Industry)	£149	plus VAT
Flowcode 10 user (Network Licence)	£399	plus VAT
Flowcode Site Licence	£799	plus VAT

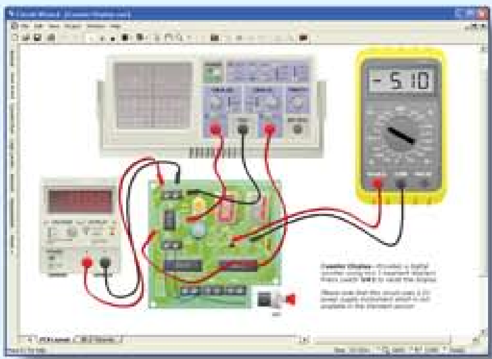
CIRCUIT WIZARD

Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
- *Interactive circuit diagram simulation*
- *True analogue/digital simulation*
- *Simulation of component destruction*
- *PCB Layout*
- *Interactive PCB layout simulation*
- *Automatic PCB routing*
- *Gerber export*
- *Multi-level zoom (25% to 1000%)*
- *Multiple undo and redo*
- *Copy and paste to other software*
- *Multiple document support*



This is the software used in our *Teach-In 2011* series.
Standard **£61.25** inc. VAT
Professional **£91.90** inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

EPE PIC RESOURCES V2

Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus 18 useful texts to help you get the most out of your PIC programming.

Price **£14.75** inc. VAT

ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

Price **£19.95** inc. VAT

Please send me: CD-ROM ORDER FORM

☐ Assembly for PICmicro V3
☐ 'C' for 16 Series PICmicro V4
☐ Flowcode for PICmicro
☐ Flowcode for AVR
☐ Flowcode for ARM
☐ Flowcode for dsPIC & PIC24

Version required:
☐ Hobbyist/Student
☐ Professional
☐ Professional 10 user
☐ Professional + Flowkit
☐ Site licence

Note: The software on each version is the same, only the licence for use varies.

☐ PICmicro Development Board V3 (hardware)

☐ Circuit Wizard – Standard
☐ Circuit Wizard – Professional
☐ EPE PIC Resources V2
☐ Electronic Components Photos

Full name: ....
Address: ....
.... Post code: .... Tel. No: ....
Signature: ....

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ ....
☐ Please charge my Visa/Mastercard/Maestro: £ ....
Valid From: .... Card expiry date: ....
Card No: .... Maestro Issue No. ....
Card Security Code .... (The last 3 digits on or just under the signature strip)

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Student/Single User/Standard/Hobbyist Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Professional, Multiple User and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU
To order by phone ring
01202 880299. Fax: 01202 843233
Goods are normally sent within seven days
E-mail: orders@wimborne.co.uk
Online shop:
www.epemag.com

DIRECT BOOK SERVICE

ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2 & 3

FREE CD-ROM

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

ELECTRONICS TEACH-IN 3

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series. The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages **Order code ETI3** **£8.50**

Book and CD-ROMs **Order code ETIBUNDLE** Bundle Price **£14.00**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS AND CDROMS SEE THE UK SHOP ON OUR WEBSITE

www.epemag.com

All prices include UK postage

2

COMPUTING AND ROBOTICS

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and home editions.
The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, notepad and paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; how to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

264 pages **Order code BP514** **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages + Large Format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision command system

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages **Order code NE36** **£25.00**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp

If you are, or soon will be, involved in the use of microprocessors and microcontrollers, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors and micrcontrollers. Assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern micros.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£29.99**

EASY PC CASE MODDING
R.A Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination. To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

192 pages + CD-ROM **Order code BP542** **£8.99**

ROBOT BUILDERS COOKBOOK
Owen Bishop

This is a project book and guide for anyone who wants to build and design robots that work first time.

With this book you can get up and running quickly, building fun and intriguing robots from step-by-step instructions. Through hands-on project work, Owen introduces the programming, electronics and mechanics involved in practical robot design-and-build. The use of the PIC microcontroller throughout provides a painless introduction to programming – harnessing the power of a highly popular microcontroller used by students, hobbyists and design engineers worldwide.

Ideal for first-time robot builders, advanced builders wanting to know more about programming robots, and students tackling microcontroller-based practical work and labs.

The book's companion website at http://books.elsevier.com/companions/9780750665568 contains: downloadable files of all the programs and subroutines; program listings for the Quester and the Gantry robots that are too long to be included in the book.

366 pages **Order code NE46** **£26.00**

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation.

Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

295 pages **Order code NE38** **£41.00**

THEORY AND REFERENCE

THE AMATEUR SCIENTIST CD-ROM

The complete collection of The Amateur Scientist articles from Scientific American magazine. Over 1,000 classic science projects from a renowned source of winning projects. All projects are rated for cost, difficulty and possible hazards.

Plus over 1,000 pages of helpful science techniques that never appeared in Scientific American.

Exciting science projects in: Astronomy; Earth Science; Biology; Physics; Chemistry; Weather . . . and much more! The most complete resource ever assembled for hobbyists, and professionals looking for novel solutions to research problems.

Suitable for Mac, Windows, Linux or UNIX. 32MB RAM minimum, Netscape 4.0 or higher or Internet Explorer 4.0 or higher.

Temporarily out of stock

OSCILLOSCOPES – FIFTH EDITION
Ian Hickman

Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.

This handy guide to oscilloscopes is essential reading for anyone who has to use a 'scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman's review of all the latest types of 'scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.

The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscillocopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.

288 pages **Order code NE37** **£36.99**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop

Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.

228 pages **Order code NE35** **£36.99**

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£5.45**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£5.49**

MICROCONTROLLER COOKBOOK
Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** **£36.99**

FULL COLOUR COMPUTING BOOKS

HOW TO FIX YOUR PC PROBLEMS **R.A. Penfold**

What do you do when your laptop or desktop stops working properly. Do you panic, try to find the answer on the page of fault finding tips you may find at the back of the manufacturers manual. Or do you spend hours trying to get through to a telephone helpline or waste even more time waiting for an email reply from a helpdesk.

Well help is now at hand! This book will assist you in identifying the type of problem, whether it's hardware, software or a peripheral that is playing up? Once the fault has been identified, the book will then show you how to go about fixing it. This book uses plain English and avoids technical jargon wherever possible. It is also written in a practical and friendly manner and is logically arranged for easy reference.

The book is divided into four main sections and among the many topics covered are: Common problems with Windows Vista operating system not covered in other chapters. Also covers to a lesser extent Windows XP problems. Sorting out problems with ports, peripherals and leads. Also covers device drivers software and using monitoring software. Common problems with hard disc drives including partitioning and formatting a new drive. Using system restore and recovering files. Also covers CD-ROM and Flash drives. Common problems with sound and video, including getting a multi-speaker system set up correctly.

An extremely useful addition to the library of all computer users, as you never know when a fault may occur!

Printed in full colour on high quality non-refective paper

128 pages **Order code BP705** **£8.49**

AN INTRODUCTION TO WINDOWS VISTA **P.R.M. Oliver and N. Kantarris**

If you have recently bought a new desktop or laptop it will almost certainly have Windows as its operating system. Windows Vista manages the available resource of a computer and also 'controls' the programs that run on it.

To get the most from your computer, it is important that you have a good understanding of Vista. This book will help you acheive just that. It is written in a friendly and practical way and is suitable for all age groups from youngsters to the older generation. It has been assumed that Vista is installed and running on your computer.

Among the numerous topics explained are: The Vista environment with its many windows. How to organise your files, folders and photos. How to use Internet Explorer for your web browsing. How to use Microsoft Mail for your emails. How to control your PC and keep it healthy. How to use Vista's Accessibility features if you have poor eye sight or difficulty in using the keyboard or mouse. And much more besides....

With the help of this book you will easily and enjoyably gain a better understanding of Microsoft's amazing Windows Vista operating system.

Printed in full colour on high quality non-refective paper

120 pages **Order code BP703** **£8.49**

COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION **R.A. Penfold**

Laptop computers have rapidly fallen in price, increased in specification and performance and become much lighter in weight. They can be used practically anywhere, then stored away out of sight. It is therefore, not surprising that laptop sales now far exceed those of desktop machines and that they are increasingly becoming the machine of choice for the older generation.

You may want to use your laptop as your main computer or as an extra machine. You may want to use your laptop on the move, at home, at work or on holiday. Whatever your specific requirements are, the friendly and practical approach of this book will help you to understand and get the most from your laptop PC in an easy and enjoyable way. It is written in plain English and wherever possible avoids technical jargon.

Among the many topics covered are: Choosing a laptop that suits your particular needs. Getting your new computer set up properly. Customising your computer so that it is optimised for your particular needs. Setting up and dealing with user accounts. Using the Windows 'Ease of Access Center'. Optimising the life and condition of your battery. Keeping the operating system and other software fully up-to-date. Troubleshooting common problems. Keeping your computer and data safe and secure. And much more besides...

Even though this book is written for the older generation, it is also suitable for anyone of any age who has a laptop or is thinking of buying one. It is written for computers that use Windows Vista as their operating system but much will still apply to Windows XP machines.

Printed in full colour on high quality non-refective paper

120 pages **Order code BP702** **£8.49**

AN INTRODUCTION TO EXCEL SPREADSHEETS **Jim Gatenby**

The practical and friendly approach of this book will help newcomers to easily learn and understand the basics of spreadsheets. This book is based on Microsoft's Excel 2007 spreadsheet, but much of the book will still apply to earlier versions of Excel. The book is written in plain English, avoiding technical and mathematical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Install the software. Use the exciting new features of Excel 2007. Create and use a spreadsheet. Enter, edit and format text, numbers and formulae. Insert and delete columns and rows. Save and print a spreadsheet. Present the information on a spreadsheet as a graph or chart. Manage and safeguard Excel files on disc. Use Excel as a simple database for names and addresses.

This book will help you to quickly gain confidence and get to grips with using spreadsheets. In fact, you will wonder how you ever managed without them.

Printed in full colour on high quality non-reflective paper.

118 pages **Order code BP701** **£8.49**

AN INTRODUCTION TO DIGITAL PHOTOGRAPHY WITH VISTA **R.A. Penfold**

The friendly and practical approach of this book will help newcomers to digital photography and computing to easily learn the basics they will need when using a digital camera with a laptop or desktop PC. It is assumed that your PC uses Windows Vista, however, if it is a Windows XP machine the vast majority of this book will still apply. The book is written in plain English, avoiding technical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Understand the basic features of a digital camera. Transfer photographs from your digital camera to your computer. View your photographs. Save, sort and file your photographs. Manipulate, crop and carry out simple corrections to your photographs. Copy your photographs on to CD or DVD. Print your photographs. Share images with family and friends anywhere in the world by email or with an online album.

This book will help you quickly get to grips with, gain confidence and expand your horizons in the fascinating hobby of digital photography.

Printed in full colour on high quality non-reflective paper.

120 pages **Order code BP700** **£8.49**

COMPUTING & PROJECT BUILDING

eBAY – TWEAKS, TIPS AND TRICKS
R. A. Penfold

NEW

Online auction sites are one of the most popular types of site on the internet, and the most popular of these is the eBay site. On eBay you can buy and sell practically anything at surprisingly low cost, and all from the comfort of your armchair!

This book contains numerous tweaks, tips and tricks covering various aspects of buying and selling on eBay. These tweaks, tips and tricks will help both new and more experienced users of the site to make the most of eBay's facilities while remaining safe and secure.

Among the many topics covered are: Finding the items you require using the eBay search facility: Getting the best prices when buying and selling on eBay: Avoiding both buying and selling scams: Determining the market value for items you intend buying or selling: How to avoid problems that may arise when buying and selling on eBay: Making the most of the various facilities that are built into the eBay site: How to take good photos of items you wish to sell using basic equipment: Using the My eBay page to stay in control of your buying and selling activities: And more besides.

128 pages **Order code BP716** **£7.50**

THE INTERNET – TWEAKS, TIPS AND TRICKS
R. A. Penfold

NEW

Robert uses his vast knowledge and experience in computing to provide you with useful hints, tips and warnings about possible difficulties and pitfalls when using the Internet. This book should enable you to get more from the Internet and to discover ways and means of using it that you may not have previously realised.

Among the many topics covered are: Choosing a suitable browser: Getting awkward pages to display properly: Using Java, spell checkers and other add-ons: Using proxy servers to surf anonymously and privacy facilities so you do not leave a trail of sites visited. Ways of finding recently visited sites you can no longer find: Using download managers to speed up downloads from slow servers. Plus, effective ways and tricks of using search engines to locate relevant info: Tricks and tips on finding the best price for goods and services: Not getting "conned" when buying or selling on eBay: Finding free software: Finding and using the increasing range of Cloud computing services: Tips on selecting the best security settings: Etc,etc,etc.

128 pages **Order code BP721** **£7.50**

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PCS
R. A. Penfold

NEW

Robert uses his vast knowledge and experience in computing to guide the reader simply through the process of finding reliable sites and sources of free software that will help optimise the performance and protect their computer against most types of malicious attack.

Among the many topics covered are: Using Windows 7 optimisation wizard: Using Pitstop for advice on improving performance, reducing start up times, etc: Free optimisation scans and the possibility of these being used as a ploy to attack your PC.

Plus, free programs such as Ccleaner, Registry checker and PCPal optimisation software: Internet speed testing sites and download managers: Overclocking sites together with warnings about using this technique: Sites and software for diagnosis of hardware faults, including scanning for out of date drivers and finding suitable replacements: Free Antivirus software and programs that combat specific types of malware: Firewalls: Search engines to identify mystery processes listed in Windows Task Manager.

128 pages **Order code BP722** **£7.50**

HOW TO BUILD A COMPUTER
R.A. Penfold

To build your own computer is, actually, quite easy and does not require any special tools or skills. In fact, all that it requires is a screwdriver, pliers and some small spanners rather than a soldering iron! The parts required to build a computer are freely available and relatively inexpensive.

Obviously, a little technical knowledge is needed in order to buy the most suitable components, to connect everything together correctly and to set up the finished PC ready for use. This book will take you step-by-step through all the necessary procedures and is written in an easy to understand way. The latest hardware components are covered as is installing the Windows Vista operating system and troubleshooting.

320 pages **Order code BP591** **£8.99**

BUILDING VALVE AMPLIFIERS
Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

BOOK ORDERING DETAILS

All prices include UK postage. for postage to Europe (air) and the rest of the world (surface) please add £2 per book. For the rest of the world airmail add £3 per book. **Note: Overseas surface mail postage can take up to 10 weeks**. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to:

DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET, BH21 1UU.

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a further selection of books see the next two issues of *EPE*.
Tel 01202 880299 Fax 01202 843233. Email: dbs@wimborne.co.uk
Order from our online shop at: www.epemag.com. Go to the 'UK store'.

THEORY & REFERENCE

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£5.49**

STARTING ELECTRONICS
Third Edition
Keith Brindley

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages **Order code NE42** **£15.99**

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date...

Card Number .... Maestro Issue No..................

Card Security Code .... Card valid from date ....
(the last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
OCTOBER '10		
Bridge Adaptor For Stereo Power Amps	770	£9.22
CDI Module For Small Motors	772	£7.96
★ LED Strobe and Tachometer – 1		
– Main Board	775 } pair	£10.04
– Switch Board	776	
NOVEMBER '10		
★Railpower – Main Board	773 } pair	£17.80
– Display Board	774	
★LED Strobe and Tachometer – 2		
– Photo-Interrupter	777 } pair	£8.58
– IR Reflect Amp	778	
★USB Clock with LCD Readout – 1	779	£9.42
Balanced MIC Preamp for PCs and MP3 Players	780	£10.46
DECEMBER '10		
12V Speed Controller or 12V Lamp Dimmer	781	£8.39
★Digital RF Level & Power Meter		
– Main Board	783 } set	£12.97
– Head-end Board	784	
– RF Attenuator Board	785	
JANUARY '11		
★Multi-Purpose Car Scrolling Display		
– Main Board	786 } pair	£14.65
– Display Board	787	
USB-Sensing Mains Power Switch	788	£11.72
★433MHz UHF Remote Switch		
– Transmitter	789 } pair	£12.14
– Receiver	790	
FEBRUARY '11		
Time Delay Photoflash Trigger	791	£11.66
Tempmaster Mk.2	792	£10.31
MARCH '11		
★GPS Synchronised Clock	793	£9.62
★Digital Audio Millivoltmeter	794	£13.61
Theremin	795	£12.64
USB Printer Share Switch	796	£8.16
APRIL '11		
Multi-Message Voice Recorder	797	£9.04
PIR-Triggered Mains Switch	798	£9.60
★Intelligent Remote-Controlled Dimmer	799	£8.36
MAY '11		
★6-Digit GPS Clock	800	£12.83
Simple Voltage Switch For Car Sensors	801	£8.16
The μCurrent (double-sided, surface mount)	802	£13.80
★Digital Audio Oscillator (double-sided)	803	£14.20
JUNE '11		
230V AC 10A Full-Wave Motor Speed Controller	804	£10.69
Precision 10V DC Voltage Reference	805	£7.77
6-Digit GPS Clock Driver (Pt.2)	806	£8.16
Musicolour IRDA Accessory	807	£7.38

PROJECT TITLE	ORDER CODE	COST
JULY '11		
Beam-Break Flash Trigger – IR Source	808 } pair	£9.72
– Detector	809	
Metal Locator	810	£8.56
Multi-Function Active Filter	812	£10.00
Active AM Loop Antenna and Amp		
– Antenna/Amp	813 } pair	£10.67
– Radio Loop (inc. Varicaps)	814	
AUGUST '11		
Input Attenuator for the Digital Audio Millvoltmeter	811	£7.58
★SD Card Music & Speech Recorder/Player	815	£13.61
★Deluxe 3-Chan. UHF Rolling Code		
Remote Control – Transmitter	816 } pair	£12.43
– Receiver	817	
SEPTEMBER '11		
★ Digital Megohm and Leakage Current Meter	818	£9.72
Auto-Dim for 6-Digit GPS Clock	819	£6.80
OCTOBER '11		
★ High-Quality Stereo DAC –		
Input & Control Board	820 } set	£20.41
Stereo DAC/Analogue Board	821	
Front Panel Switch	822	
Power Supply Board	823	
Twin Engine SpeedMatch Indicator	824	£8.75
★ Wideband Air/Fuel Display (double-sided)	825	£14.38
NOVEMBER '11		
★ Digital Capacitor Leakage Meter	826	£10.11
One-of-Nine Switch Indicator		
– Main Board	827 } pair	£11.27
– Remote Display Board	828	

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code **Project** **Quantity** **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**) to:

Everyday Practical Electronics

MasterCard VISA Maestro

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . . Maestro Issue No. . . . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:

http://www.epemag.com

CLASSIFIED

ADVERTISEMENTS

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it. We have been the leading monthly magazine in this market for the last twenty-five years.

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).
All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: epeads@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

MISCELLANEOUS

ADVERTISERS INDEX

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU

PHONE: 01202 880299 **FAX:** 01202 843233
EMAIL: epeads@wimborne.co.uk **WEB:** www.epemag.com

For editorial address and phone numbers see page 7

Next Month

Ginormous 7-Segment LED Panel Meter Display

Have you ever needed a digital display that can be read from across the room? How about across the factory? How about fifty or even a hundred metres away? This exciting project features a large 150mm 7-segment display made from special 'light bars'. Each digit comes with two opto-isolated inputs, enabling RS485, RS232 or USB control; you can even create a 10-digit run.

WIB: Web Server In a Box – Part 1

We're very excited about this three-part project. It will let you house your own website with hundreds or even thousands of pages, all in a little box connected to the internet via a modem/router. You don't need a computer to operate and house a website – this little box does it all for you, and it can be accessed from anywhere around the world, at any time, even from a mobile phone which has a web browser. In fact, it is a complete web server in a box – so we've called it WIB (Web server In a Box).

Using a wideband O2 sensor in your car – Part 2

December brings the construction and installation details of this super-charged automotive project, which lets you fine-tune your car's engine. We'll show you how to build it and then move on to test details, including tailpipe sensing. No self-respecting 'petrolhead' should be without it!

DECEMBER '11 ISSUE ON SALE 10 NOVEMBER

Content may be subject to change

Published on approximately the second Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £21.95 (6 months); £41.50 (12 months); £78.00 (2 years). OVERSEAS: standard air service, £25.00 (6 months); £48.00 (12 months); £91.00 (2 years). Express airmail, £35.00 (6 months); £68.00 (12 months); £131.00 (2 years). Payments payable to "Everyday Practical Electronics", Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.